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FLIGHT MEASUREMENT OF AIRCRAFT ANTENNA RADIATION PATTERNS

October 1975
Final Report

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This report describes the technique developed at the Air Force Flight Test Center (AFFTC) for dynamic measurements of aircraft antenna radiation patterns in the presence of multipath radiation. A background on antenna pattern measurement techniques, flight pattern techniques, theory of multipath radiation, and documentation of computer software developed for postflight reduction of data are presented.

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The technique developed uses recorded signal strength and aircraft position data collected during skidding turns to produce computer generated plots (CDC 6500). The data is corrected for multipath radiation by computer predicted multipath gain at each data point. The resulting data is plotted offline with a CALCOMP plotter.

PREFACE

This report presents the results of a study effort to develop an improved technique for the flight measurement of aircraft antenna radiation patterns at the Air Force Flight Test Center (AFFTC), Edwards AFB, California. The study effort and tests were authorized by the Aircraft Antenna Pattern Synthesis Technique Study Plan, February 1974, and the Test Plan for Evaluating Techniques of Determining Aircraft Antenna Radiation Patterns, August 1974. The tests were conducted in October 1974 and December 1974 under Job Order Number SC6341. The results of the tests, which were used to show the validity of the data processing techniques, are shown in appendix D of this report.

The format of this report was developed to make this report more usable to Project Engineers of the Systems Engineering Branch at AFFTC. As such, information is presented to give a novice, in the field of antenna radiation pattern measurement, sufficient background and knowledge to perform an accurate evaluation of aircraft antenna radiating systems.

The author wishes to acknowledge the following individuals who were instrumental in the preparation of this report: Mr. B. Lyle Schofield, Chief, Flight Test Technology Branch, for guidance and editorial comments; Mr. Alfred H. Boyd, Systems Engineer, for providing technical expertise; Sgt James N. Robertson, Engineering Aide, for assisting in the development of the computer software; and our secretaries Mrs. Dorothy M. Shaffer and Miss Mary Jane Gugliotte for their tireless efforts in transforming this report into its final form.

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INTRODUCTION

The dynamic measurement of aircraft antenna radiation patterns has been a time consuming task which usually produced results of marginal utility. The classical cloverleaf flight pattern, used in the past, produced one antenna pattern with 12 to 24 data points and required 1 1/2 to 3 hours of flying time. The severe limitation of the minimal data samples and the high cost of flying time has rendered this technique obsolete and created a requirement for an improved method.

The techniques reported here were developed to provide the Systems Engineer with the tools necessary to conduct an accurate and efficient evaluation of aircraft antenna systems. To accomplish this, a semi-automated system was developed which permits the aircraft to fly a variety of flight patterns and produces continuous 360 degree antenna patterns.

The concepts of dynamic measurement of aircraft antenna patterns presented in this report are the results of a survey of the field of antenna pattern measurement. The technique developed at the Air Force Flight Test Center (AFFTC) drew upon the concepts being used by Rome Air Development Center (RADC), Naval Air Test Center (NATC), and others. The result has been the development of an efficient dynamic aircraft antenna pattern measurement system.

This system was developed and tested in the Fall of 1974. The initial testing was accomplished at the Precision Antenna Measurement System (PAMS) at Griffiss AFB, New York. PAMS is the most modern dynamic antenna measurement facility in the Air Force and data collected there was used as a standard for comparing techniques. Further testing was accomplished at Edwards AFB using a C-131 and an F-15 aircraft. The results of these tests are shown in appendix D.

The body of this report presents information which can be used by a Systems Engineer to conduct an efficient and accurate evaluation of an aircraft antenna system. The report is arranged such that it can be used as a handbook for planning, testing, analyzing, and reporting tests by Systems Test Engineers.

Appendix B and C of this report provide documentation of two sets of computer programs. These programs constitute a complete data reduction package to assist in the planning of flights, processing of radar position tapes and signal strength tapes, and plotting of measured effective radiated power (ERP) of each received signal.

AIRCRAFT ANTENNA PATTERN MEASUREMENT TECHNIQUES

There are several techniques available to measure aircraft antenna radiation patterns. Each technique has advantages and disadvantages and each vary in accuracy, cost, complexity, and usage. This section will present an introduction to each of the four basic techniques: (1) theoretical, (2) modeling, (3) dynamic, and (4) near-field. No attempt is being made to present all the details of each technique, but only to present the basic concepts of each and how

they are used. If a more detailed understanding of each of these techniques is desired additional material referenced in the bibliography may be used.

THEORETICAL

The theoretical calculation of the radiation pattern of an antenna mounted on a complex structure, an aircraft for example, has only become feasible with the development of the modern high speed computers (reference 1). Since the computation involves the solution of numerous differential equations, this technique is dependent upon the speed of the computer. Normally, the use of this technique has been restricted to initial design stages where the goal is to locate the antenna in the best position which will produce an acceptable radiation pattern.

The main advantage of this technique is that the radiation pattern of an antenna can readily be evaluated at various locations on the aircraft once the aircraft structure is modeled into the computer. This permits the rapid, low cost evaluation of aircraft antenna radiation patterns and allows the designer to locate the position on the aircraft which has the best probability of producing the most optimal pattern.

The prime disadvantage of this technique is its sensitivity to errors. Aircraft VHF and UHF antenna radiation patterns can be very sensitive to small dimensional errors in modeling parts of the aircraft structure. The area within the near-field region of the antenna (within a few wave lengths) is especially susceptible to these discrepancies. Since the aircraft structure is only approximated in the computer program, the calculated patterns can have numerous discrepancies.

A number of computer programs have been written which calculate the theoretical radiation pattern of antennas mounted on complex structures. Each program uses approximation techniques to model the shape of the aircraft. The most common technique is the wire-grid approximation which approximates the aircraft structure by a series of wires. Figure 1 shows a typical wire-grid approximation model. A second modeling technique is the geometric approximation which approximates the aircraft structure with a series of simple geometric shapes (reference 2).

Both of these methods only provide approximate shapes of the aircraft's actual structure; therefore, the accuracy of the final result will depend upon the significant deviation of the approximated aircraft structure from the actual structure. Hence, the accuracy of the prediction will depend upon the user's ability to include all significant portions of the aircraft's structure in the model. Because these approximations can never eliminate all errors in the shape of the structure, theoretical patterns should be considered as producing an approximate shape of the actual antenna pattern.

MODELING

The modeling method is the technique most often used to measure antenna radiation patterns. This technique uses a model of the aircraft mounted on a pedestal which rotates the model around its axis while the

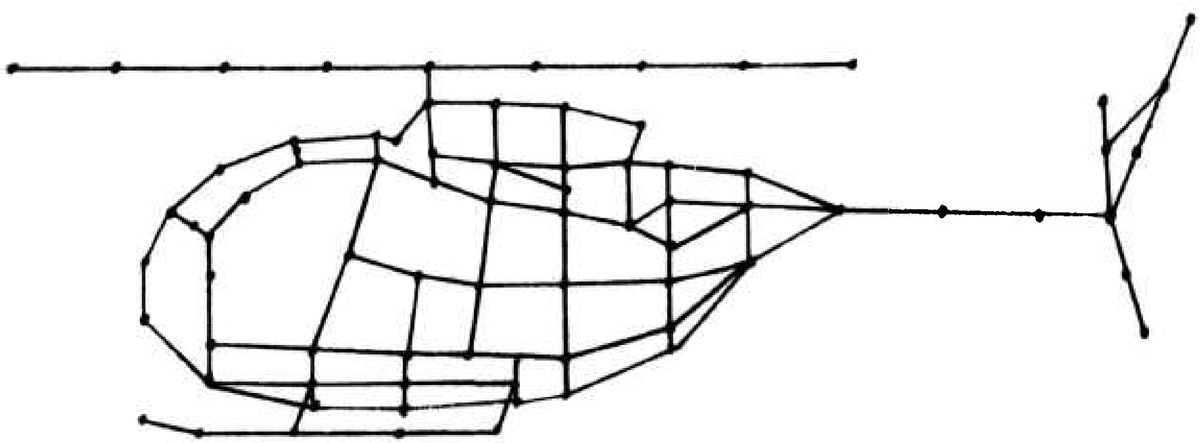


Figure 1 Wire-grid Model of Helicopter

antenna patterns are measured. The models can be of any size and are normally mounted in an anechoic chamber or an outdoor range. RF absorbing material will cover all surfaces which may cause unwanted reflected signals. The largest of these facilities is located at RADC's Stockbridge Range, where an actual B-52G is mounted and rotated on a pedestal (figure 2).

With the modeling technique, the transmitter is normally mounted within the aircraft and the frequency increased by 1/N, where N is the fraction of the model size. Therefore, a 1/4 scale model will require the frequency to be increased by a factor of four to create an equivalent pattern. To obtain an accurate model the conductivity and permittivity of the model's surface should be increased by the same amount. In an effort to accomplish this, the surface of the model is normally coated with copper which will increase the conductivity as much as economically feasible (reference 3).

The cost and the ease of measuring antenna patterns are the main advantages of the modeling technique. Since the model is mounted on a pedestal, all depression angles can easily be measured at a relatively low cost per pattern.

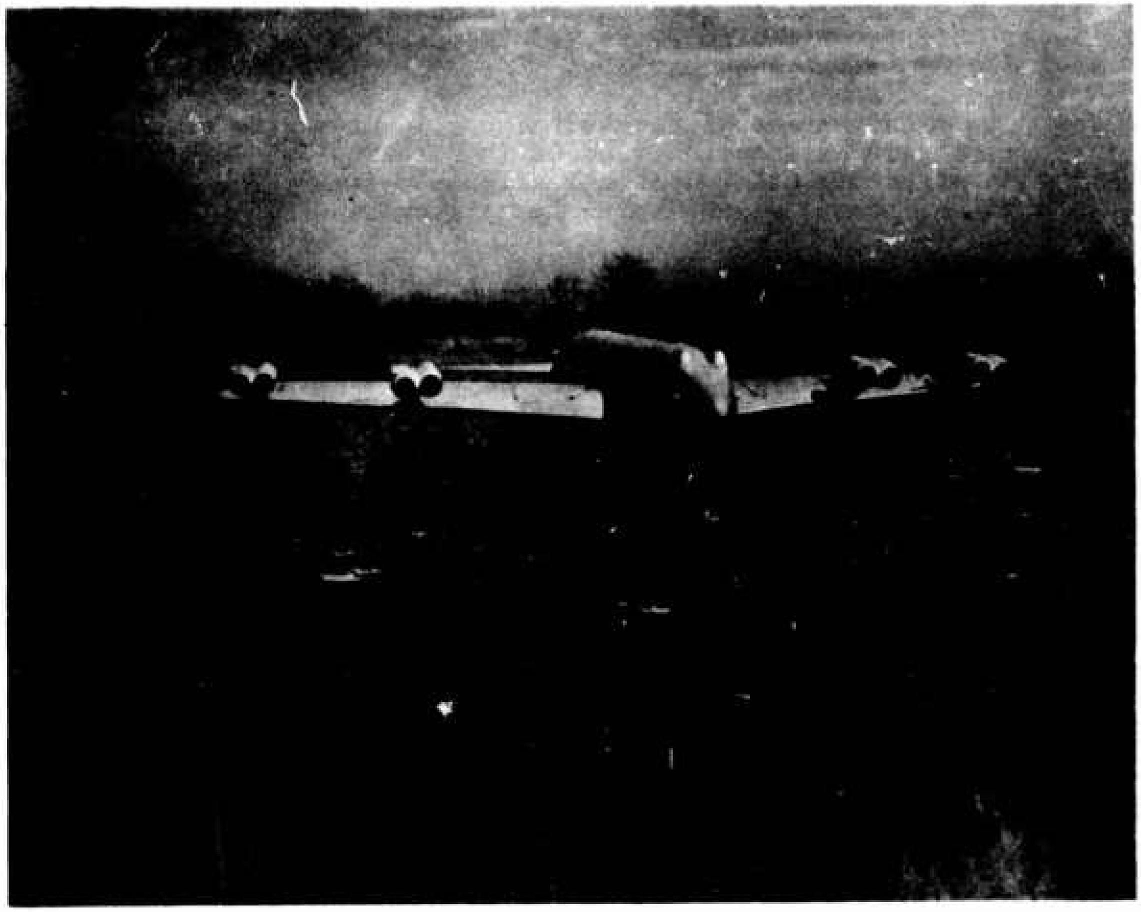
The most accurate antenna patterns are produced when a full scale model is used and care is taken to avoid the effects of the pedestal and reflected signals. When scaled models are used, the accuracy of the patterns will depend upon the precision of the model. Small dimensional errors in the model can produce major errors in the measured patterns. Additionally, to create valid patterns careful consideration must be given to effects of supporting pedestal, cables, and other equipment which are not part of the actual aircraft. Due to these problems, model patterns may contain holes which do not exist in the actual antenna system.

DYNAMIC

Dynamic measurements of aircraft antenna radiation patterns are the final checks of the antenna performance. With flight evaluation, the aircraft is placed in its operational environment and is completely isolated from external structure, like supporting pedestals and cables. Ideally the aircraft should be placed in space and rotated about its axis while a receiver on the ground records the signal strength at all depression and azimuth angles. Since this is impossible, the aircraft is flown through a variety of flight paths such that the signal strength, at all depression and azimuth angles of interest, is measured. Normally only the lower hemispherical pattern is measured with this technique, since the aircraft would be required to fly inverted to measure the upper hemisphere from the ground. A variety of flight paths which can be used is presented in detail in a latter section in this report.

NEAR-FIELD

The near-field technique of measuring antenna radiation patterns has been one of the newest developments. This technique, which basically consists of automatic scanning of the antenna within the



Note: The B-52 is in the inverted position for lower hemispherical antenna pattern measurement.

Figure 2 Stockbridge B-52G Range

near-field region and extrapolating the data to the far-field, was developed at the National Bureau of Standards by D. M. Kerns (reference 4). This method has been used at microwave frequency range producing excellent results. Figure 3 shows a typical test in an anechoic chamber. Conceptionally, this technique can be applied to VHF/UHF frequencies. Therefore, it may be possible to apply this technique to measure some types of aircraft antenna radiation patterns in the future.

One advantage of this technique is that the ground reflections and incidence reflections in anechoic chambers are eliminated because of the close proximity of the measuring probe to the antenna. Where there is strong atmospheric attenuation, such as in the millimeter-wave range, this technique is very useful since the far-field is determined from near-field measurements.

The main disadvantage of the technique, in measuring aircraft VHF/UHF antenna pattern, is the location of the probing antenna. Since the aircraft structure will alter the antenna pattern, the probing antenna must be located beyond the outer structure.

MULTIPATH RADIATION

Multipath signals are sources of some of the most significant errors when dynamically measuring aircraft antenna radiation patterns in the VHF/UHF range. These errors result from the reception of a direct signal and reflected signal simultaneously, with the reflected signal changing phase due to the difference in path length and reflection. The reception of the reflected signal is capable of producing changes in signal strength of over 18 db. Due to the magnitude of this effect, care must be taken to avoid influencing the antenna pattern with multipath radiation. Therefore, this section is included to give an understanding of the considerations required to conduct flight evaluations of antenna patterns in the presence of multipath radiation.

In the study of multipath radiation, the desired result is the magnitude of the vector sum of the direct signal and all the reflected signals received at the antenna. If both the receiver and transmitter were located in free space, only the direct signal would be received with its strength reduced by the amount of spherical dispersion. When the earth is placed in this environment, the received signal is altered. The direct ray will become curved due to atmospheric refraction and multiple signals will be received due to surface reflections. The resultant signal may show a loss or a gain, due to the phase differences between the direct and reflected signals.

Since a smooth earth and true standard atmosphere do not exist, the simple two path propagation model is modified by several factors. Reed and Russell (reference 5) list a number of factors which tend to cause variations in multipath propagation. These include:

1. Irregular terrain, such as hills and valleys, which cause reflected signals 1/2 wave length out of phase with the direct ray.

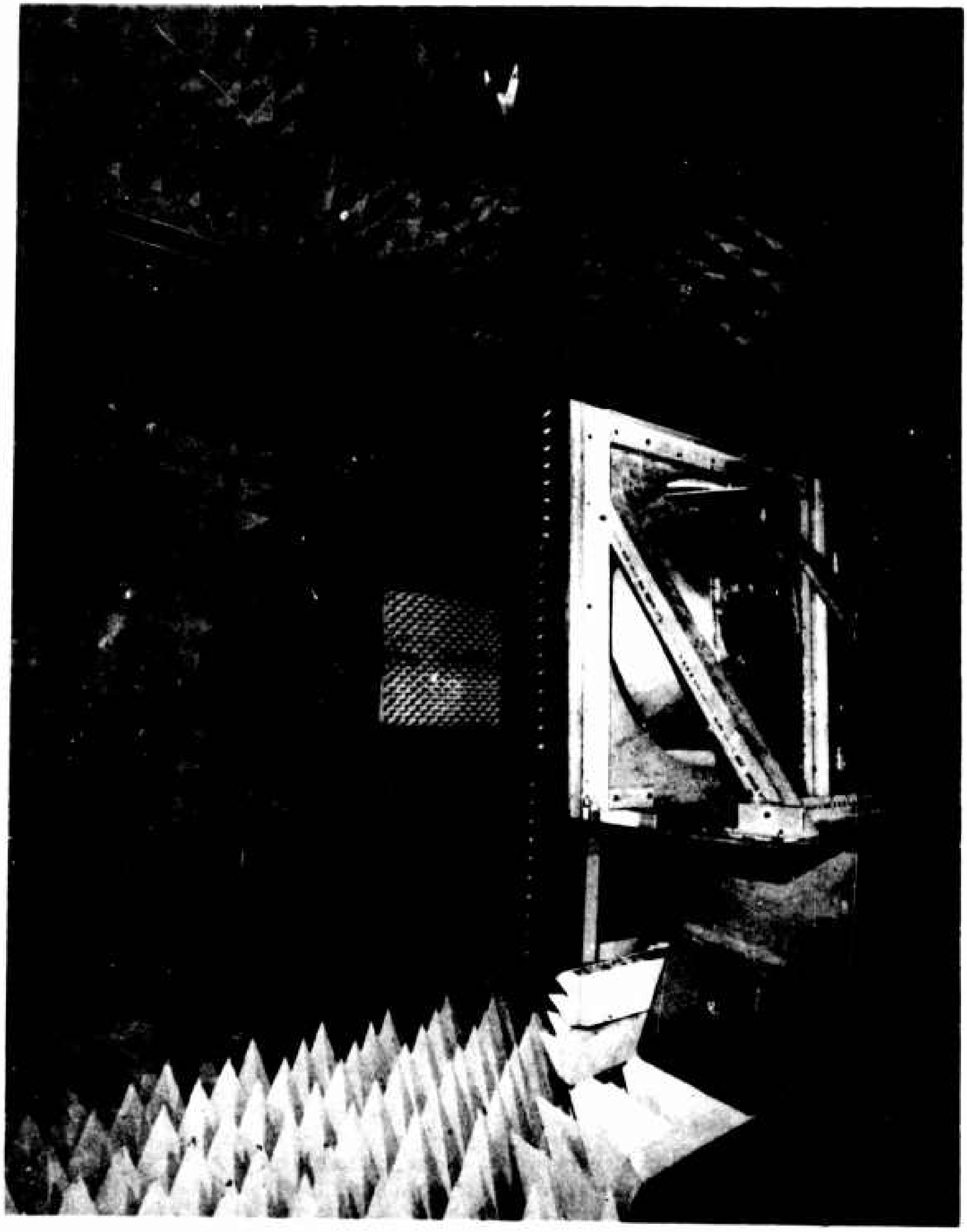


Figure 3 **Near-Field Measurement**

2. Absorbing or reflecting objects located near the ground antenna, i.e., trees, buildings, etc.

3. Aircraft structure located near the antenna which can cause absorption or reflection of radiated signal.

4. Non-standard atmosphere.

5. Atmospheric turbulence.

6. Changes in reflecting surface conductivity and permittivity which cause changes in reflection coefficient.

To effectively use the method of calculating effects of multipath propagation presented in appendix E, care must be taken to minimize these factors. The following are a number of the precautions which must be taken for the accurate prediction of the effects of two-path propagation.

1. The receiving antenna must be isolated from structures which may cause reflections of signals to the antenna or interfere with the reflected signal being calculated. Some objects which may cause this are locating the antenna near a roof or locating the antenna near buildings.

2. In order to minimize the effects of non-standard atmosphere and atmospheric turbulence, the flights should be planned during periods of stable atmospheric conditions. This will mean to avoid flying during the hot summer afternoons when rapidly rising thermals are present.

3. Changes in conductivity and permittivity of the reflecting surface can have a pronounced effect on the reflected signal. To minimize these effects the flights should be planned with constant surface conditions. This will mainly require flights to be made only when the soil is dry.

SENSITIVITY TO ERRORS

When the technique presented in appendix E is used to predict the effect of multipath radiation on the received signal, the effects of changes in the input parameters should be understood. Figures 4 through 7 show the effects of changing various parameters as predicted by the multipath option of the Antenna Data Analysis Program (ADAP) described in appendix C. The parameters changed in these figures are: (a) ground antenna height, (b) aircraft height, (c) permittivity of the reflecting surface, and (d) conductivity of the reflecting surface. There are numerous other factors which can affect the actual reception of multipath radiation. These include: surface roughness, turbulent atmosphere, and multiple reflects. Through careful flight planning these effects can be minimized.

The importance of each parameter in contributing to errors in the calculated multipath effect is a function of the ability to accurately measure the parameter and the effect the parameter has on the calculation. Therefore, if changes in a parameter can have major effects on the predicted multipath radiation, but the parameter is easily measured with a

high degree of accuracy, the parameter will be relatively unimportant for error consideration. Frequency is one such parameter since it can be accurately measured, is very stable, and has a major effect on the calculated value.

The two main parameters, which produce the majority of the errors in the prediction of the multipath effect, are the height of the antenna above the reflecting surface and the permittivity of the reflecting surface. The reason for their importance is that they are difficult to accurately measure and they have major effects on the prediction of multipath radiation.

The effect of errors in the height of the ground antenna can be seen in figure 4. This figure shows that with a change in the height of the antenna above the reflecting surface of eight feet will produce a significant change in the predicted lobe structure. An increase in the height of the antenna will increase the number of lobes and reduce the distance between each lobe. These errors can be caused by both errors in measuring the antenna height and changes in terrain. Since the terrain is not normally flat, this probably is the major cause of errors in the height of the antenna.

The effect of errors in the height of the aircraft above the reflecting surface can normally be neglected. Figure 5 shows the predicted effects of multipath radiation at two different aircraft altitudes. The effect is to increase the distance between lobes as the aircraft distance above the reflecting surface is increased. Since the aircraft altitude can be easily measured to within $\pm$500 feet, these errors normally have little effect on the accuracy of the predicted multipath gain.

The effects of changing the permittivity can be seen in figure 6. This figure shows that permittivity affects the predicted gain but has very little effect on the location of the lobes. Additionally, permittivity has a very large range of possible values. For soil the relative permittivity has a range of 2 to 30.

Conductivity of the reflecting surface is the one parameter which affects both the predicted gain and the location of the lobes. Figure 7 shows the effects of changes in conductivity on the prediction of multipath signals. This shows that only for high conductivities does the change in conductivity have any significant effect on the predicted gain. Since earth normally has a conductivity between 0.1 and 0.00001, the effects of changes in conductivity can be minimized. This can be accomplished by only flying when the surface is dry.

The use of Rogers Dry Lake at Edwards AFB for a reflecting surface appears to be ideally suited for use of predicted multipath radiation effects. The surface is relatively flat and, due to lack of moisture, has constant permittivity and conductivity throughout most of the year. This enables the direct signal strength to be determined to within $\pm$2 db.

In case the flight must be conducted when moisture is present on Rogers Dry Lake, the conductivity must be adjusted to produce the correct lobe structure. This can best be accomplished by flying outbound and inbound radials to measure the multipath effect and use

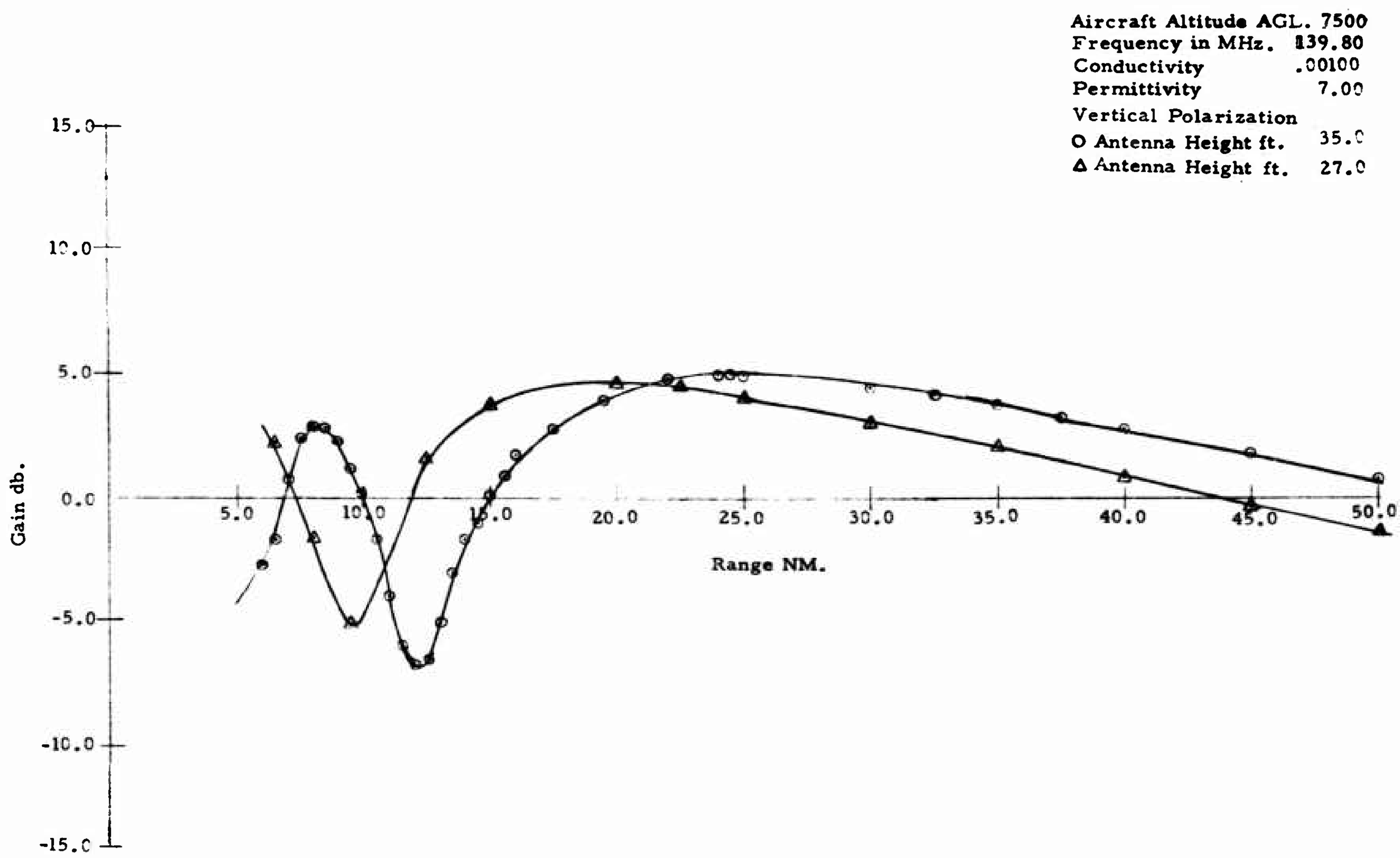


Figure 4 Effect of Antenna Height Errors on Multipath

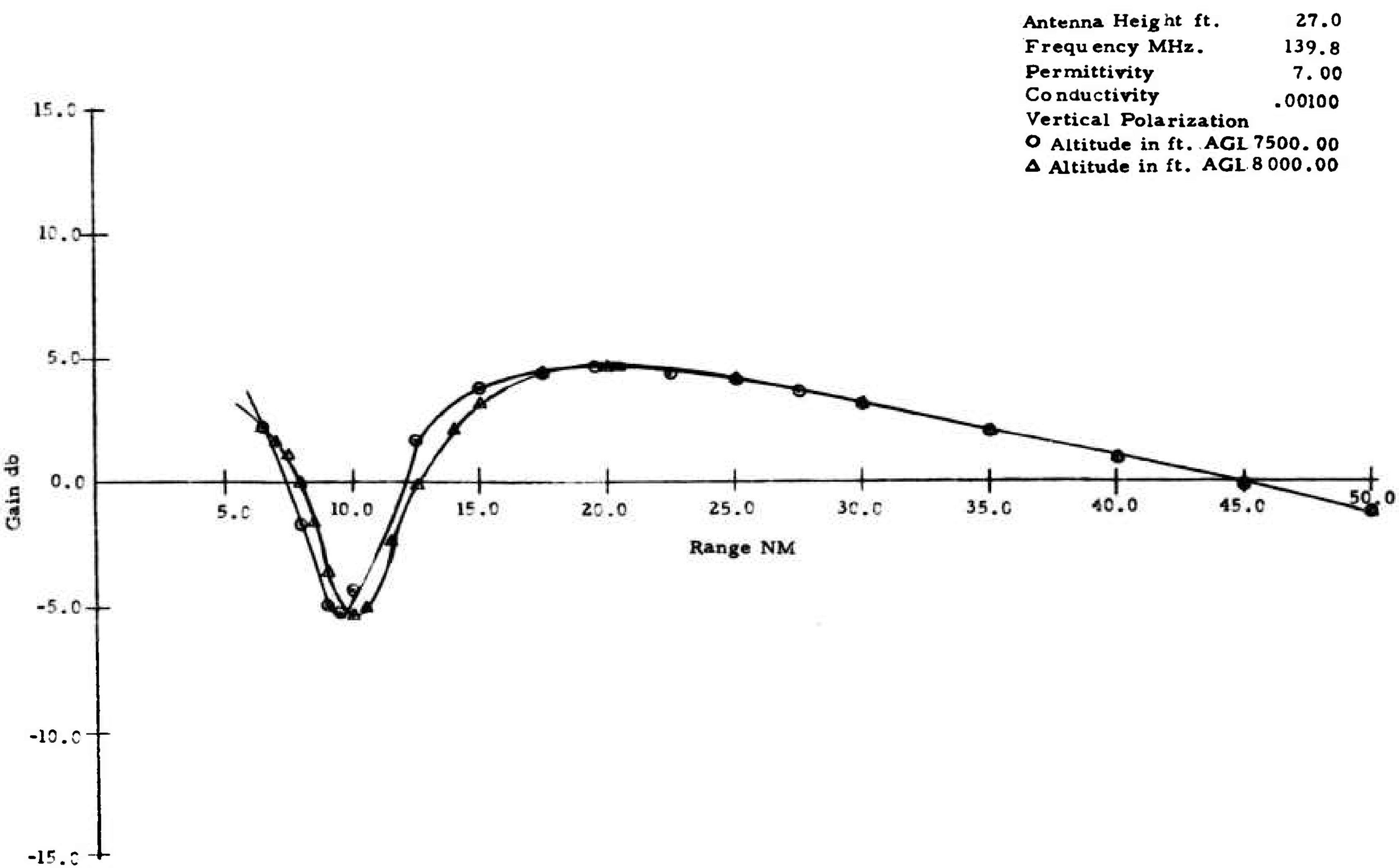


Figure 5 Effect of Aircraft Altitude Errors on Multipath

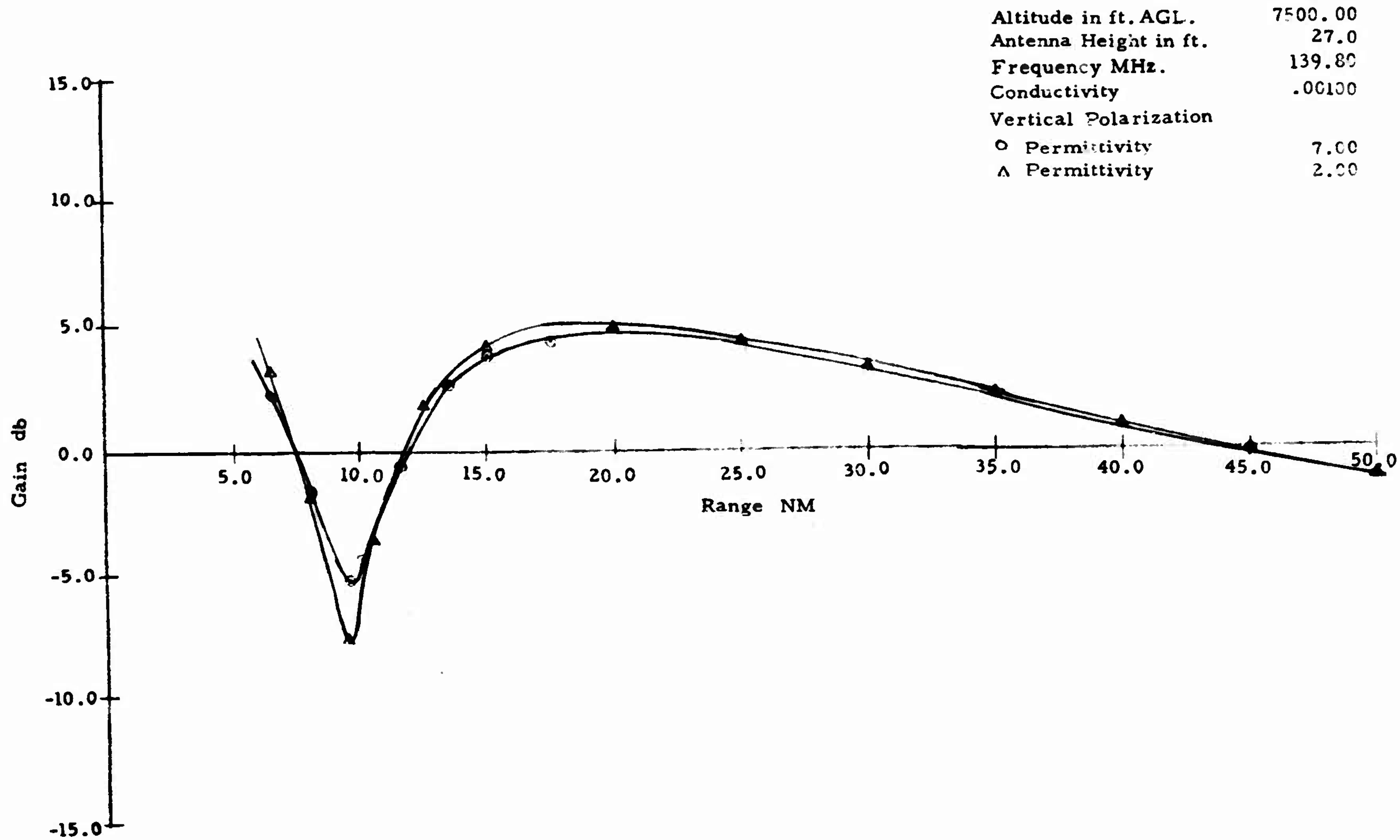


Figure 6 Effect of Permittivity Errors on Multipath

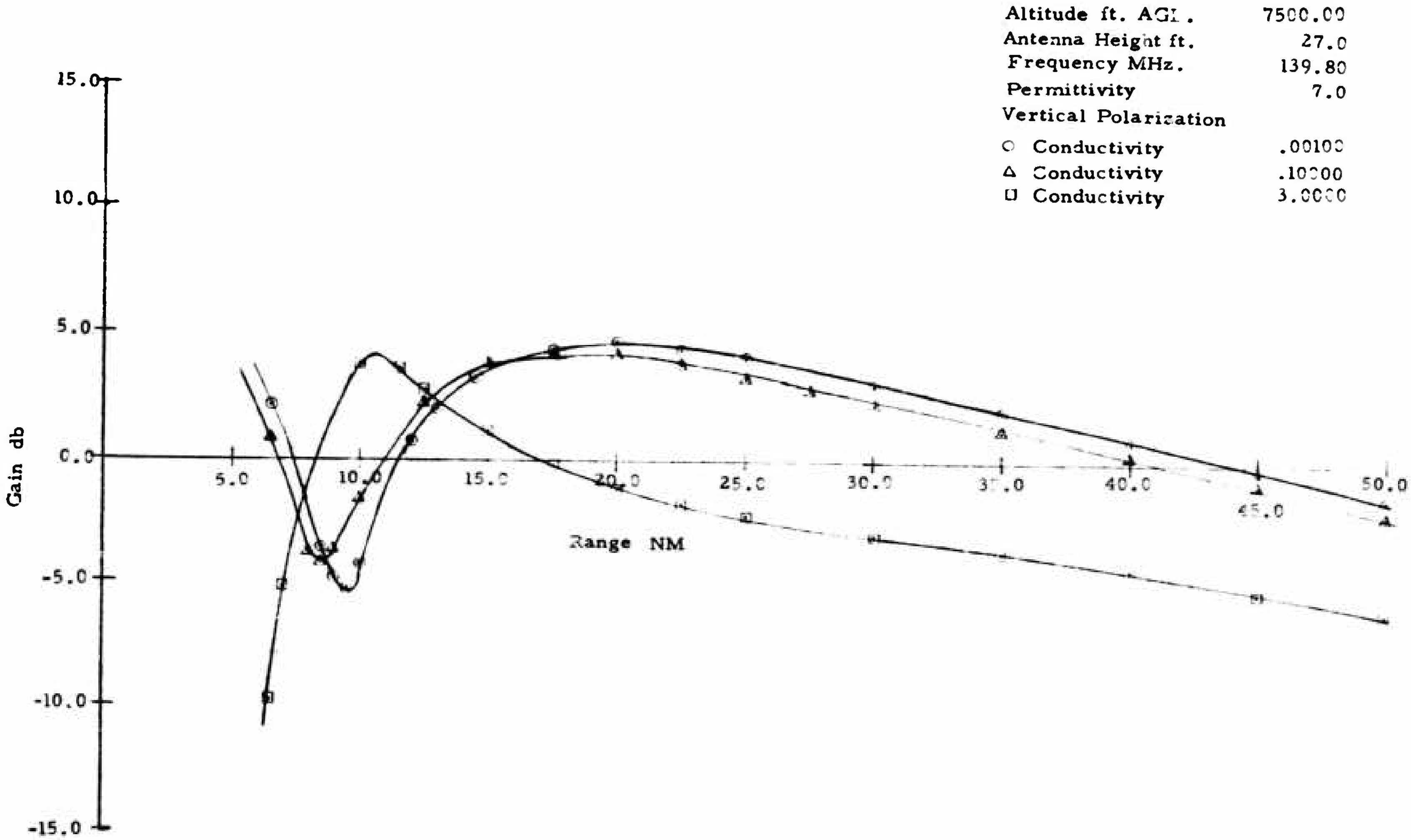


Figure 7 Effect of Conductivity Errors on Multipath

the MULT option of ADAP (appendix C) to predict the multipath structure at different conductivities. The conductivity which produces the best match of the measured nulls and lobes should be used in the reduction of the data by the Antenna Radiation Pattern Measurement Program (ARPMP appendix B).

USE OF COMPUTER PROGRAM

The technique of calculating the effects of multipath, as presented in appendix E, is available in the computer program ADAP (see appendix C). As a part of ADAP the computer program MULT will calculate the multipath effect at a given altitude, ground antenna height, frequency, conductivity, and relative permittivity. The program creates line printer plots plus a listing of all data points calculated (figure 8).

This program can be useful for planning flight paths for the measurement of aircraft antenna patterns. By predicting the lobe structure, the flight path can be determined to keep the aircraft within an area of reinforced signals.

Figure 9 shows the effect of multipath radiation on a radial flown at 7500 feet AGL. Figure 8 shows the predicted change in the signal due to multipath and figure 10 shows the radial corrected for multipath radiation. When flight evaluations of antennas are conducted, the patterns flown must avoid the null areas to produce meaningful results. Even though the Antenna Radiation Pattern Measurement Program (ARPMP appendix B) has the option of calculating the multipath effect, accuracy is lost when data is collected within the areas of deep nulls. Therefore, by using program MULT, the locations of deep nulls can be predicted and the flight pattern designed to keep the aircraft out of the null areas.

FLIGHT TECHNIQUES

The key to efficient dynamic measurement of aircraft antenna radiation patterns is the selection of an appropriate flight pattern which can produce the data desired in a minimum of flight time. To accomplish this, a number of flight techniques are available. Depending on the capability of the aircraft and the type of antenna patterns to be measured, one of the flight techniques listed in this section will produce the best antenna pattern in the shortest flight time. For most cases where 360 degrees of aspect angle are to be measured at 0 to -5 degrees depression angle, the skidding turn flight pattern should be used.

CLOVERLEAF

The cloverleaf flight pattern is the typical pattern used in the past to measure aircraft antenna patterns. The majority of these patterns are 12, 18, or 24 point cloverleafs (figure 11). The pattern should be flown at a range and altitude required to measure the depression angle of interest and at the same time keep the center of the pattern within a major lobe of the ground antenna pattern. This will insure the strongest signal is received and will minimize the errors due to changes in multipath radiation. The normal method used to accomplish this is to pick the range and altitude first and then adjust the height of the receiving antenna to place a major lobe at that point.

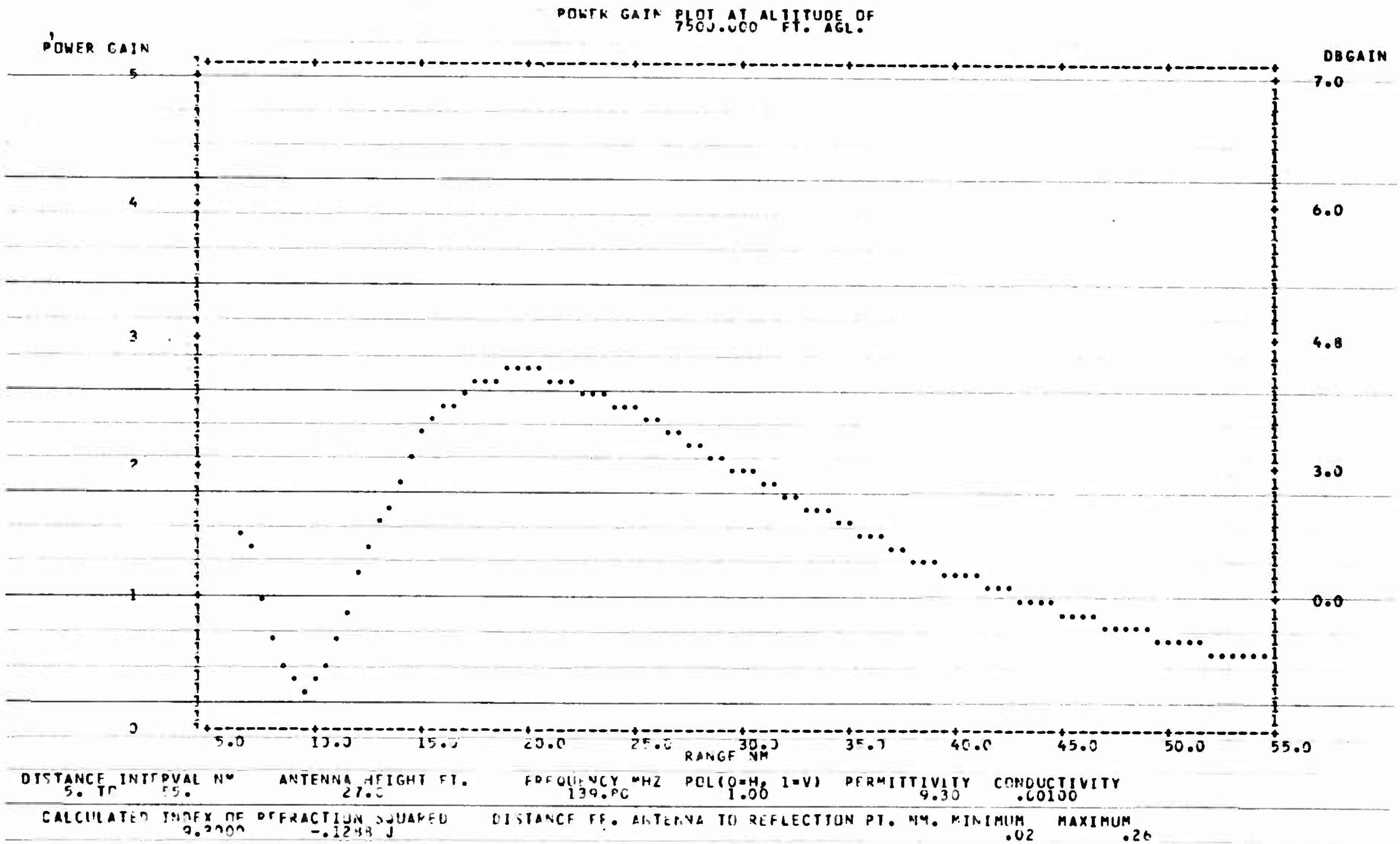


Figure 8 Predicted Multipath Effect

Figure 8 (Continued)

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GAIN (DB)	.85	.75	.65	.51	.49	.30	.17	.07	-.06	-.16
ELEV. ANG (DEG)	1.77	1.75	1.72	1.70	1.68	1.66	1.64	1.62	1.61	1.59
REF. DIST. (NM)	.17	.17	.17	.18	.18	.18	.18	.19	.19	.19
RANGE (NM)	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50
GAIN (DB)	-.29	-.38	-.51	-.64	-.73	-.85	-.97	-1.09	-1.21	-1.32
ELEV. ANG (DEG)	1.57	1.55	1.54	1.52	1.50	1.49	1.47	1.46	1.44	1.43
REF. DIST. (NM)	.20	.20	.20	.21	.21	.21	.22	.22	.22	.23
RANGE (NM)	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50
GAIN (DB)	-1.44	-1.55	-1.67	-1.78	-1.92	-2.02	-2.13	-2.26	-2.40	-2.50
ELEV. ANG (DEG)	1.41	1.40	1.39	1.37	1.36	1.35	1.33	1.32	1.31	1.30
REF. DIST. (NM)	.23	.23	.24	.24	.24	.25	.25	.26	.26	.26

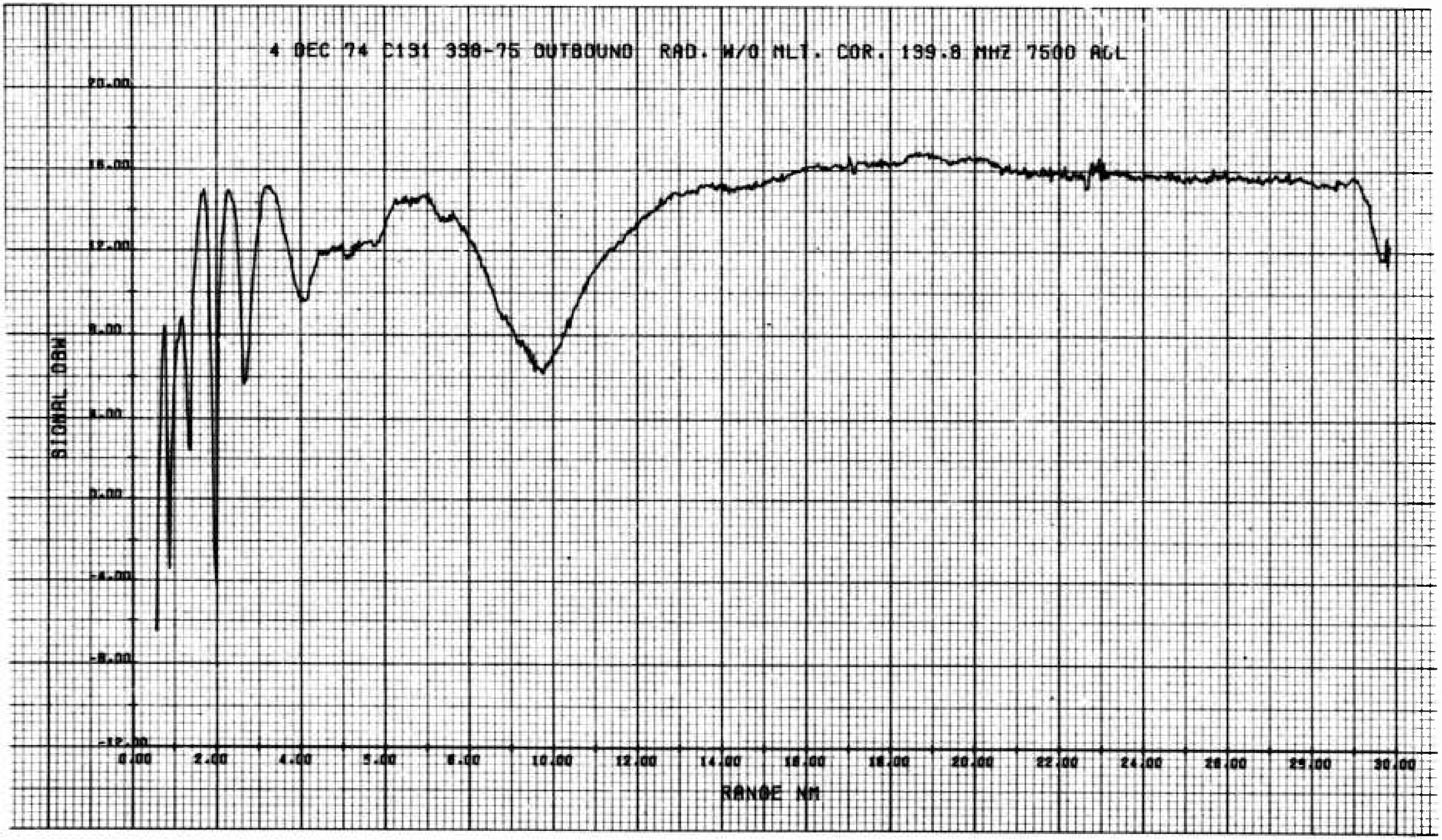


FIGURE 9 MEASURED MULTIPATH EFFECT

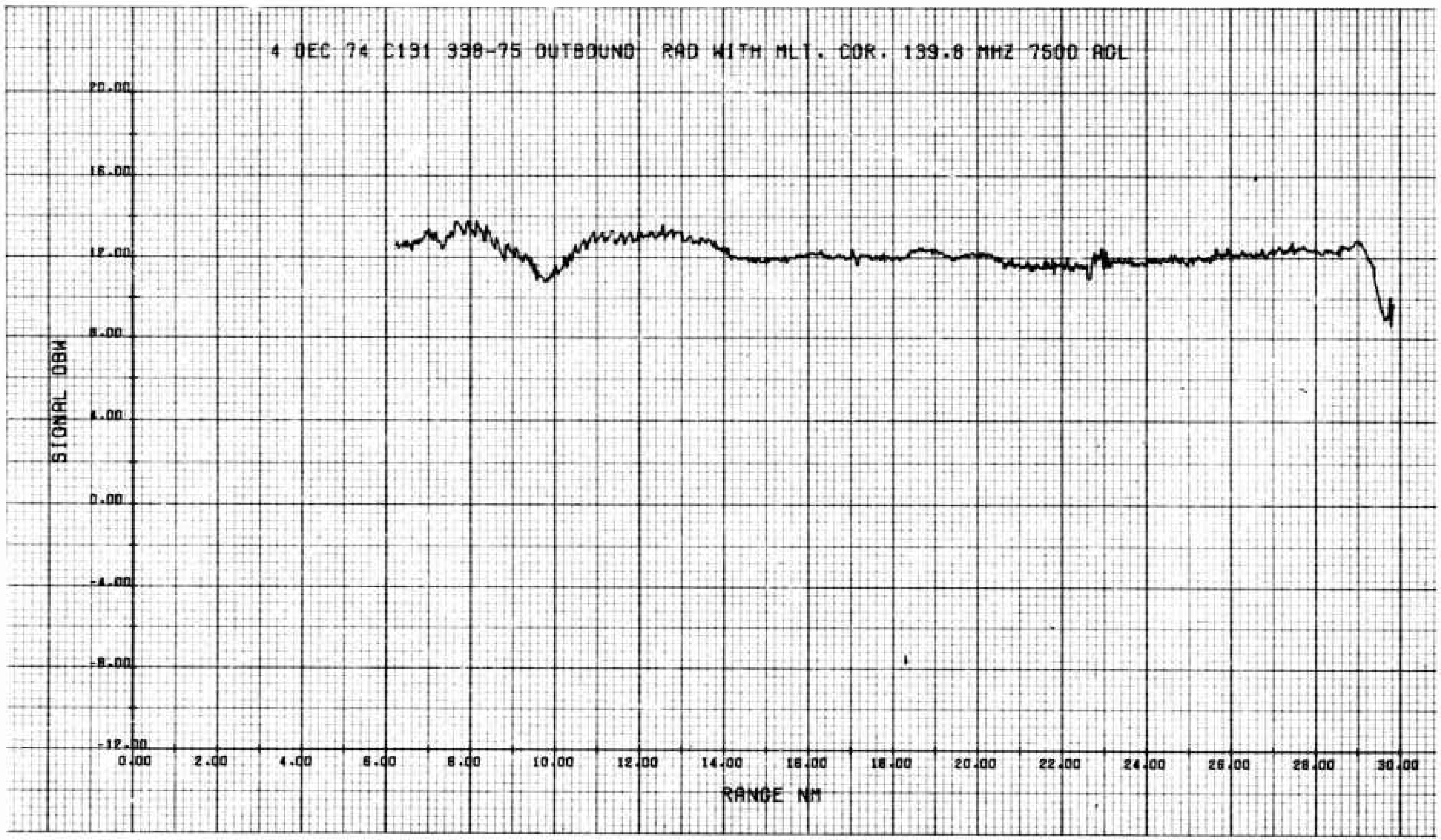
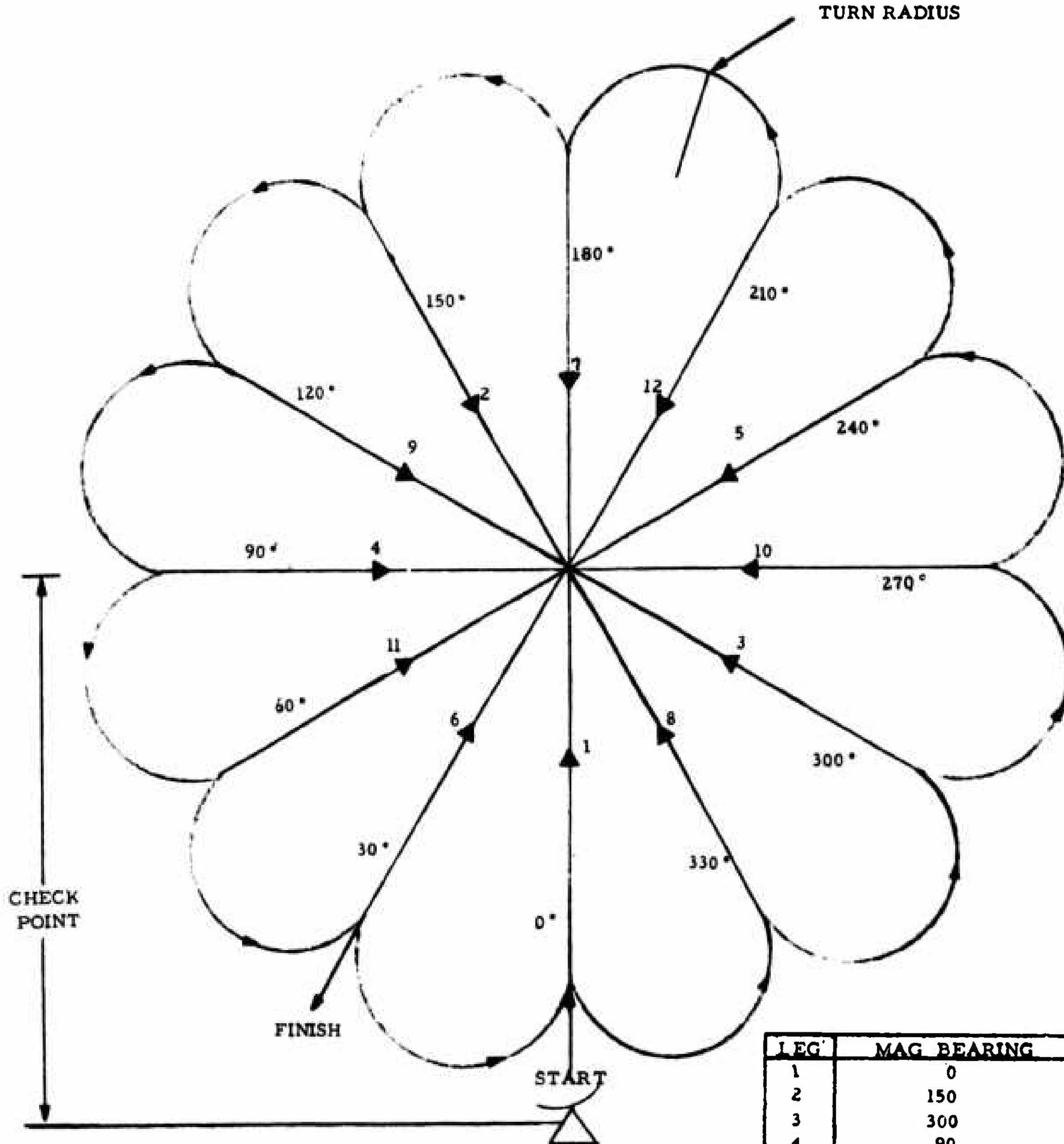


FIGURE 10 RADIAL CORRECTED FOR MULTIPATH



LEG	MAG BEARING
1	0
2	150
3	300
4	90
5	240
6	30
7	180
8	330
9	120
10	270
11	60
12	210

Figure 11 Cloverleaf Flight Pattern

Once the location for cloverleaf is determined, the aircraft can be either radar vectored over the point at the proper heading or the pilot can maneuver the aircraft over the point by using a predominant landmark as the center point. If radar tracking is not used the aircraft should pass within 1/2 NM of the center to produce accurate data. An error of 1 NM can produce 1 db change in the received signal as a result of range and multipath signal. Therefore, to insure the data is not affected by changes in range and multipath, the signal strength should only be measured when the aircraft is within 1/2 NM of the cloverleaf center.

The major advantage of this pattern is that the signal strength is measured when the aircraft is over the same point each time. This will tend to minimize the errors caused by multipath signals and atmospheric attenuation. Another advantage of this pattern is that the time required to maneuver the aircraft from each data point permits the data to be recorded with a manual system. Consequently, an automated system is not required for this flight technique.

The cloverleaf has two major disadvantages: (1) flight time required, and (2) quality of antenna patterns produced. The flight time required for a 24 point cloverleaf can vary from 1 1/2 to 3 hours depending upon the type of aircraft flown. Since only 24 data points are measured, the vast majority of the flight is required solely for maneuvering the aircraft and not collecting data. This is reflected in the quality of the antenna patterns produced. Figures 12 and 13 show two antenna patterns measured using an 18 point cloverleaf and a skidding turn. The severe limitation of this flight technique can be seen by comparing the two antenna patterns. Major holes can exist in the actual antenna pattern and would not be detected using the cloverleaf technique. Therefore, this flight technique is of only limited use.

PARALLEL FLYBYS

The parallel flyby pattern consists of a series of offset radials flown past the ground antenna (figure 14). The length of each leg and the distance of each offset is determined such that all depression angles and aspect angles of interest are measured.

The legs of a parallel flyby pattern measure depression angles of the decaying sine wave form (figure 15). As the altitude of the aircraft is lowered, the depression angles measured will approach the horizontal.

When flying this type of pattern the radar controller must be able to visually extrapolate the aircraft course from a small flight segment. This will be required to vector the aircraft to the proper leg and keep it from drifting off course. To insure the aircraft will at least parallel the plotted course, specific headings should be called to the aircraft rather than just the changes in headings. All aircraft heading changes made after the start of the leg must be recorded with the IRIG "B" time for use in the master data reduction program (ARPMP).

The most critical portion of the flight to keep the aircraft on course is the legs within 10 NM from the ground antenna. Slight errors

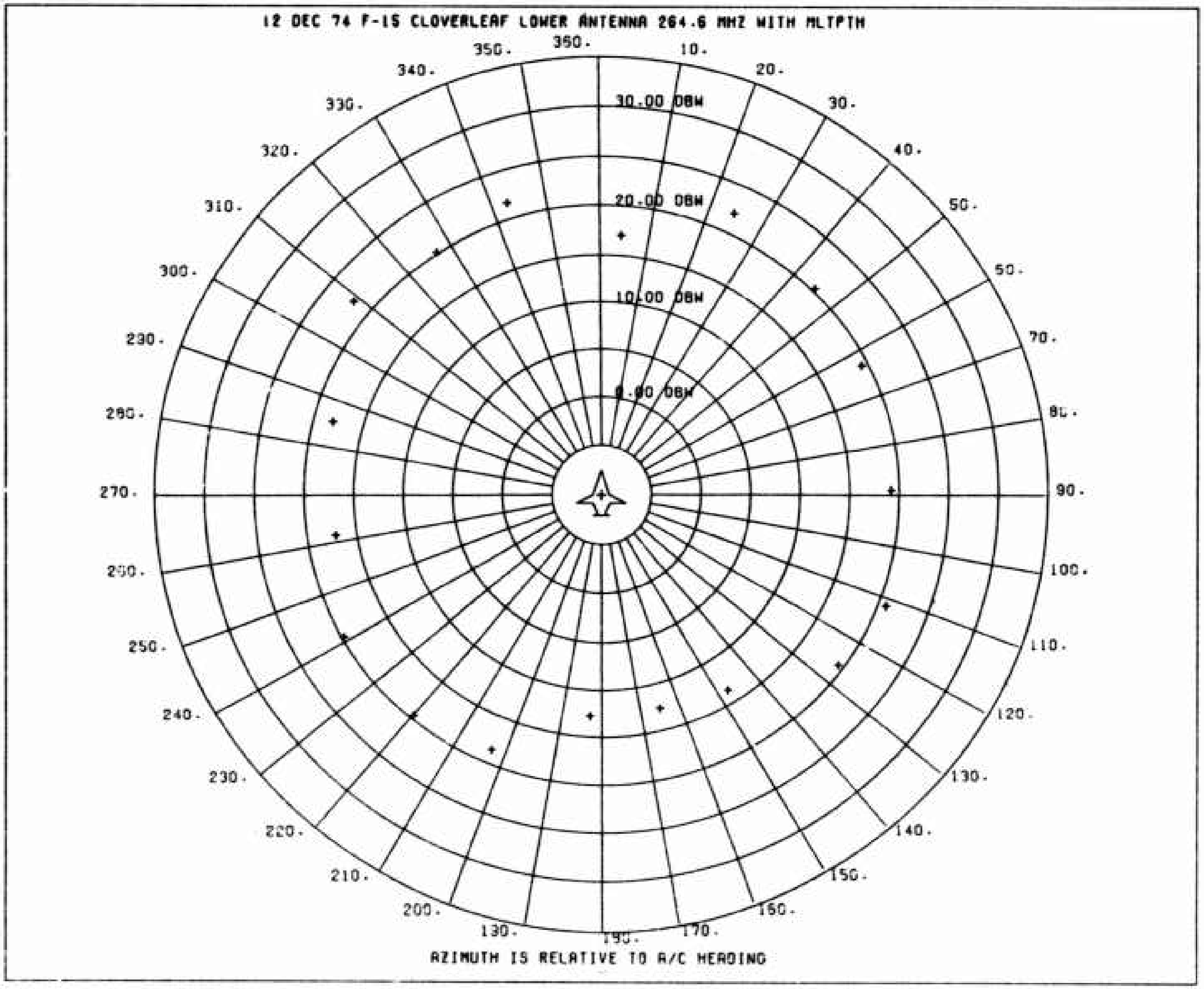


FIGURE 12 CLOVERLEAF ANTENNA PATTERN

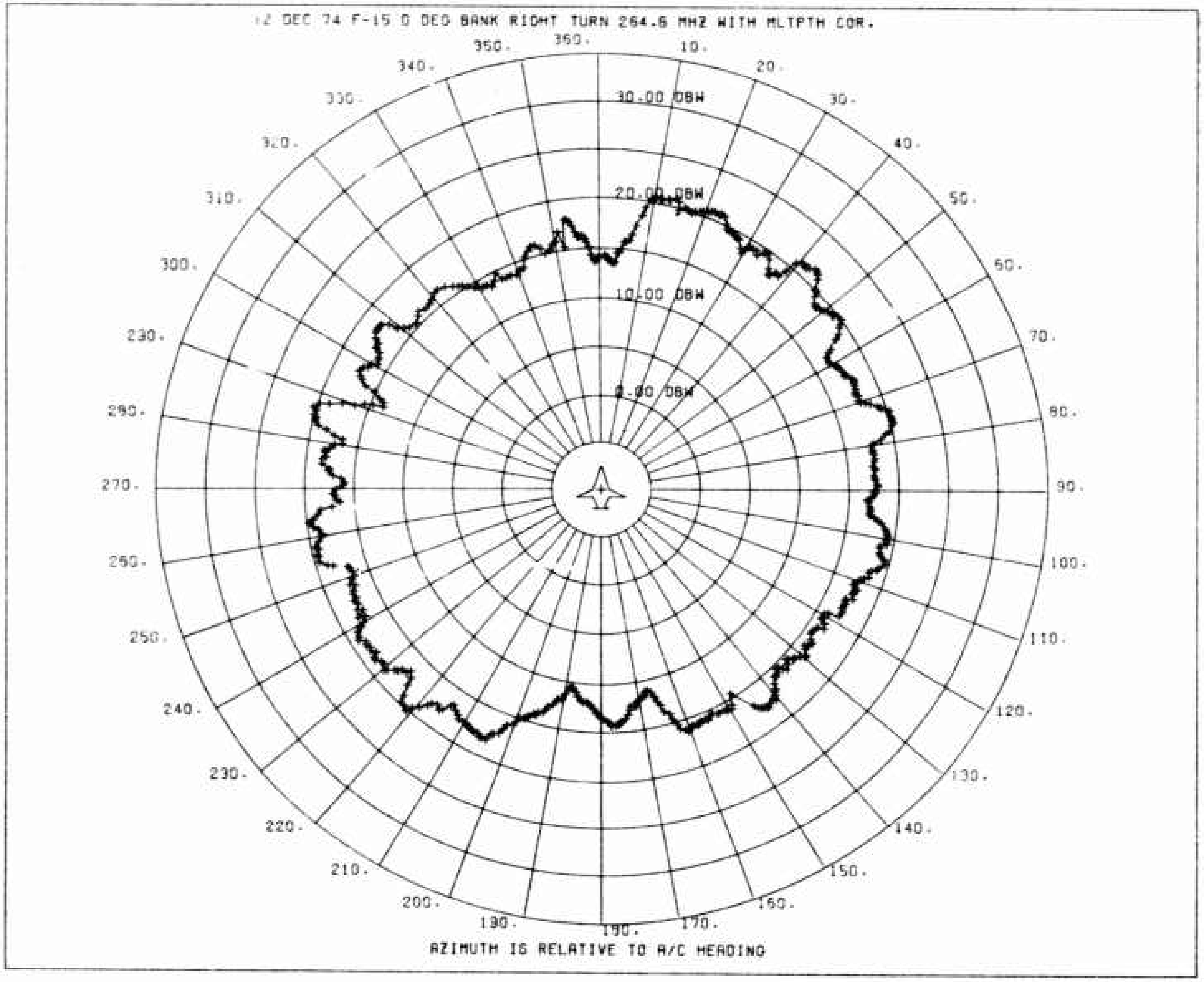


FIGURE 13 SKIDDING TURN ANTENNA PATTERN

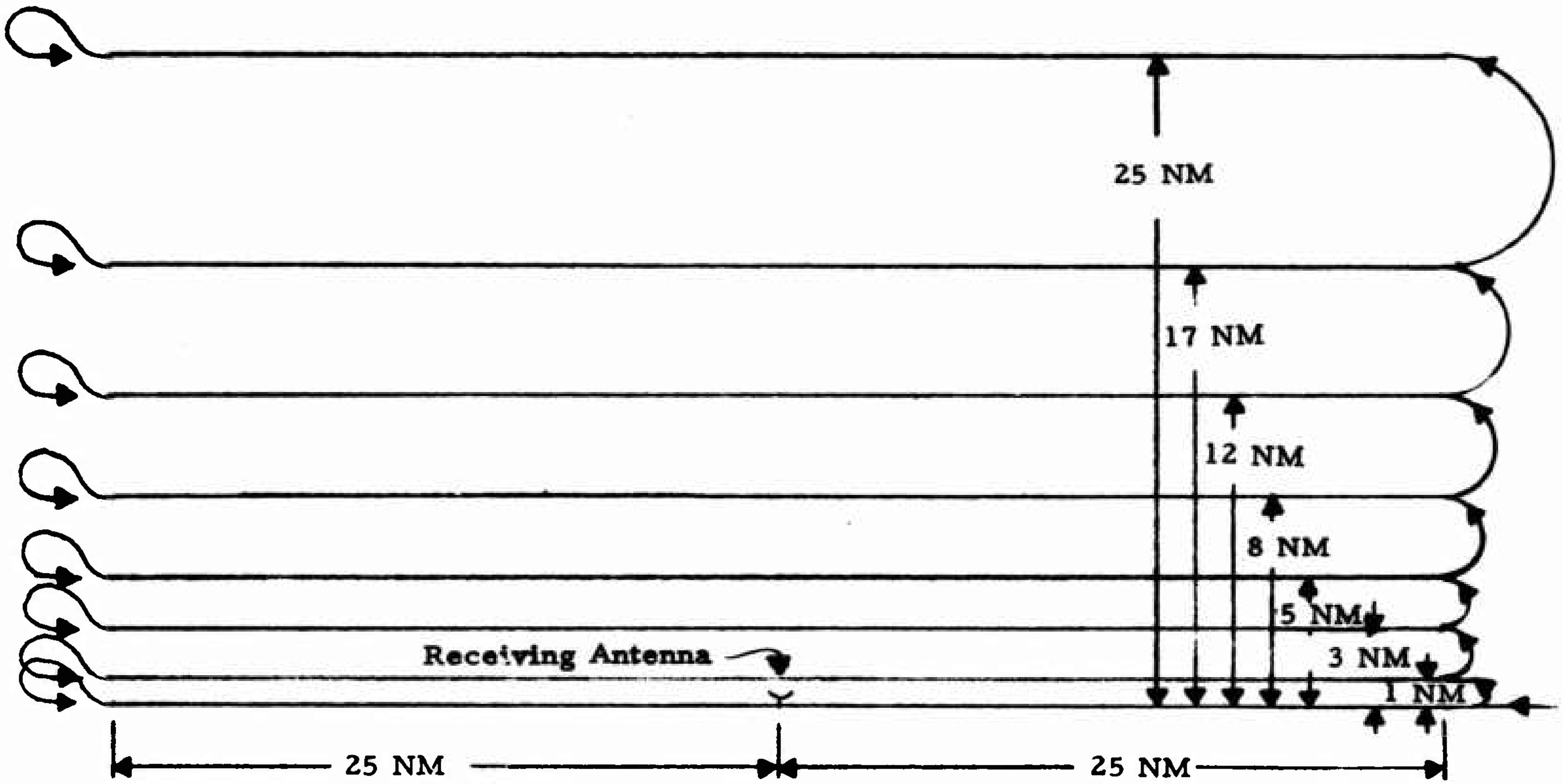


Figure 14 Parallel Flyby Flight Pattern

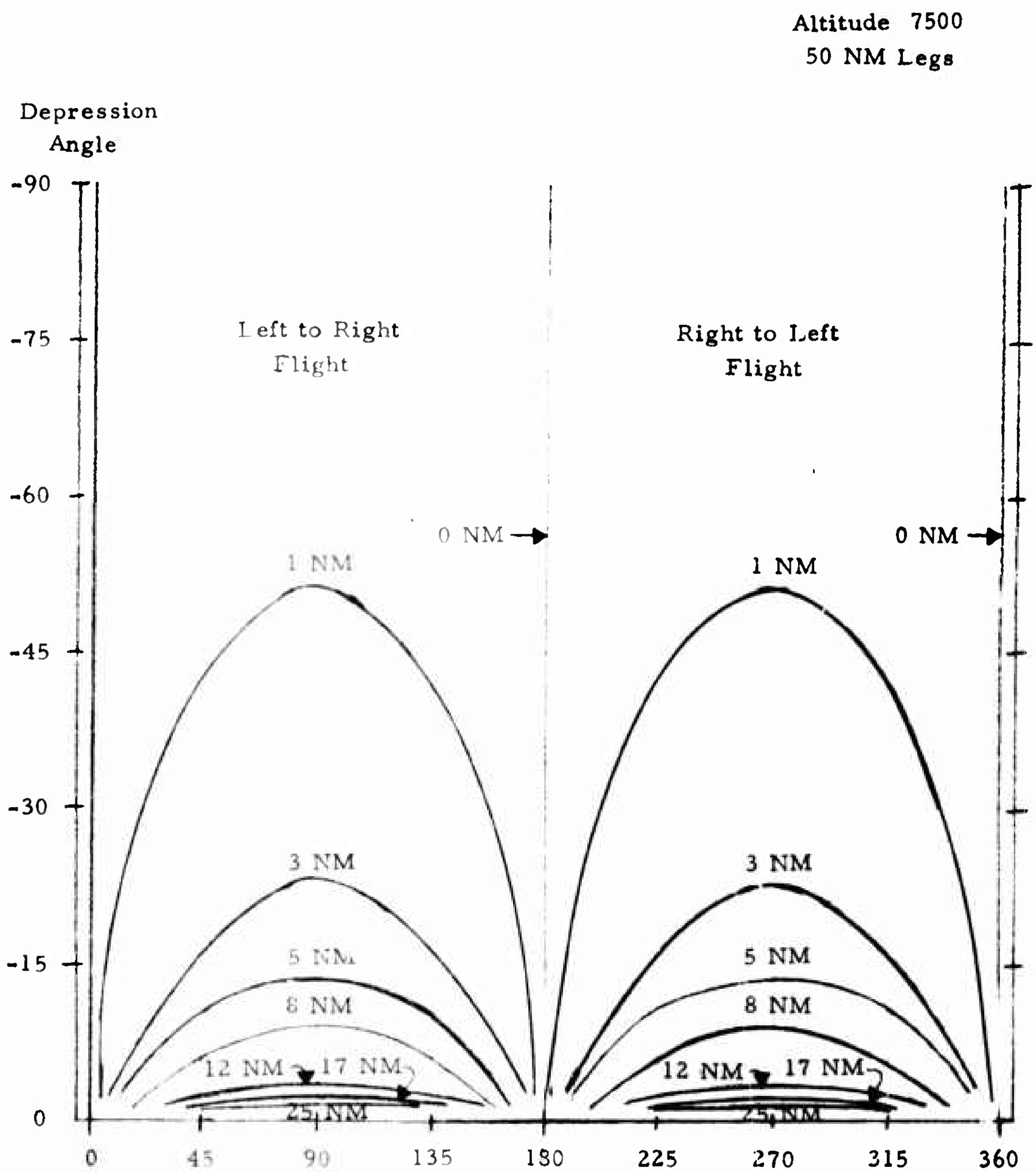


Figure 15 Parallel Flyby Depression Angle Coverage

in the course on these legs will produce major errors in the aspect and depression angles measured.

The major advantage of this type of flight pattern is that the complete lower hemisphere can be measured with a high number of data samples. Therefore, a high degree of accuracy can be obtained for effectively all the depression angles in the lower hemisphere of the aircraft in two to four hours of flight time.

The major disadvantage of this flight technique is that for valid data to be collected, the multipath signal must be eliminated. The best method to accomplish this is to use high directional receiving antennas. This is satisfactory for frequencies above 1000 MHz in which a six foot diameter dish will produce a sufficiently narrow beam. However, for frequencies between 100 MHz and 300 MHz the antenna dish would have to be up to ten times the size of the 1000 MHz antenna. Since an antenna this large is impractical to use, the multipath signal cannot be eliminated by the receiving antenna.

An alternate approach is to use the multipath prediction program to calculate the magnitude of the effect. This method of eliminating multipath signals is only usable for reflection angles of less than 12 degrees. Approximations used in deriving the equations makes the calculations inaccurate above 12 degrees. Therefore, the elimination of the multipath signal by prediction can only be used for near 0 degrees depression angle measurement.

MODIFIED PARALLEL FLYBYS

The modified parallel flyby technique is essentially a parallel flyby except the flight path has been altered to keep the aircraft within a major lobe of the ground antenna pattern (figure 16). This flight technique is designed to measure a specific depression angle where the parallel flyby technique will measure effectively the complete lower hemisphere. The modified parallel flyby is conducted in the same manner as the parallel flyby technique. The aircraft should be radar vectored to the beginning of each leg allowing sufficient time to insure the aircraft is on course before the start of the leg. To insure the aircraft is at least parallel to the correct course, the pilot should be given specific headings rather than just the heading change when being radar vectored.

The advantage of this type of flight pattern is that it has the same high number of data samples as the parallel flyby technique; yet, the data is only collected in the reinforced regions of the ground antenna pattern. Therefore, the data collected is not biased by major nulls. An additional advantage of this technique is that the airspace required to fly the pattern is reduced.

The major disadvantage is the flight time required to complete the pattern. To create a continuous 360 degree antenna pattern up to 32 individual legs must be flown. Another disadvantage is the difficulty to insure data samples are obtained at all aspect angles. Since each leg produces a small interval in aspect angle, a small error in the aircraft's path can cause specific aspect angles to be missed.

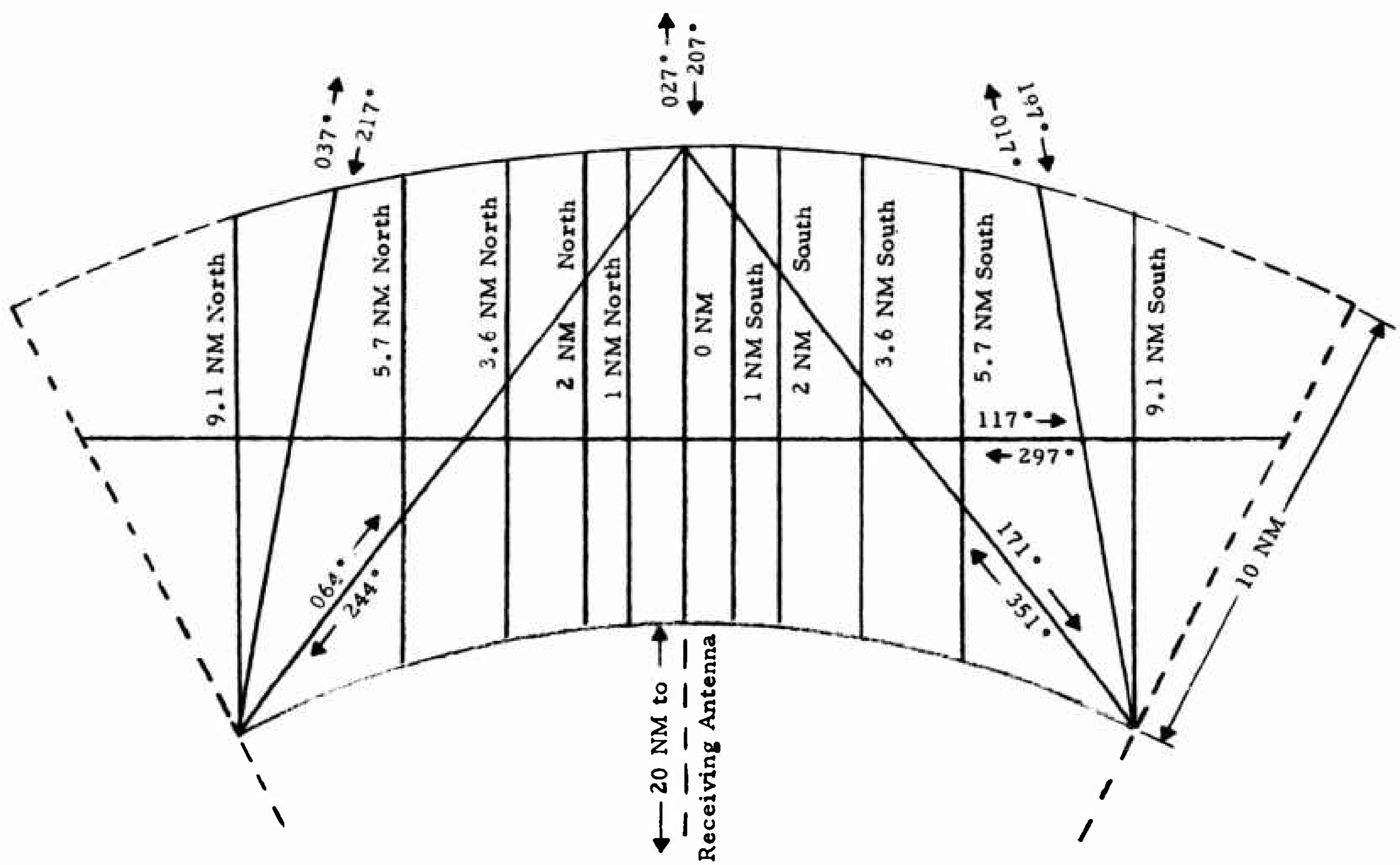


Figure 16 Modified Parallel Flyby Flight Pattern

SKIDDING TURN

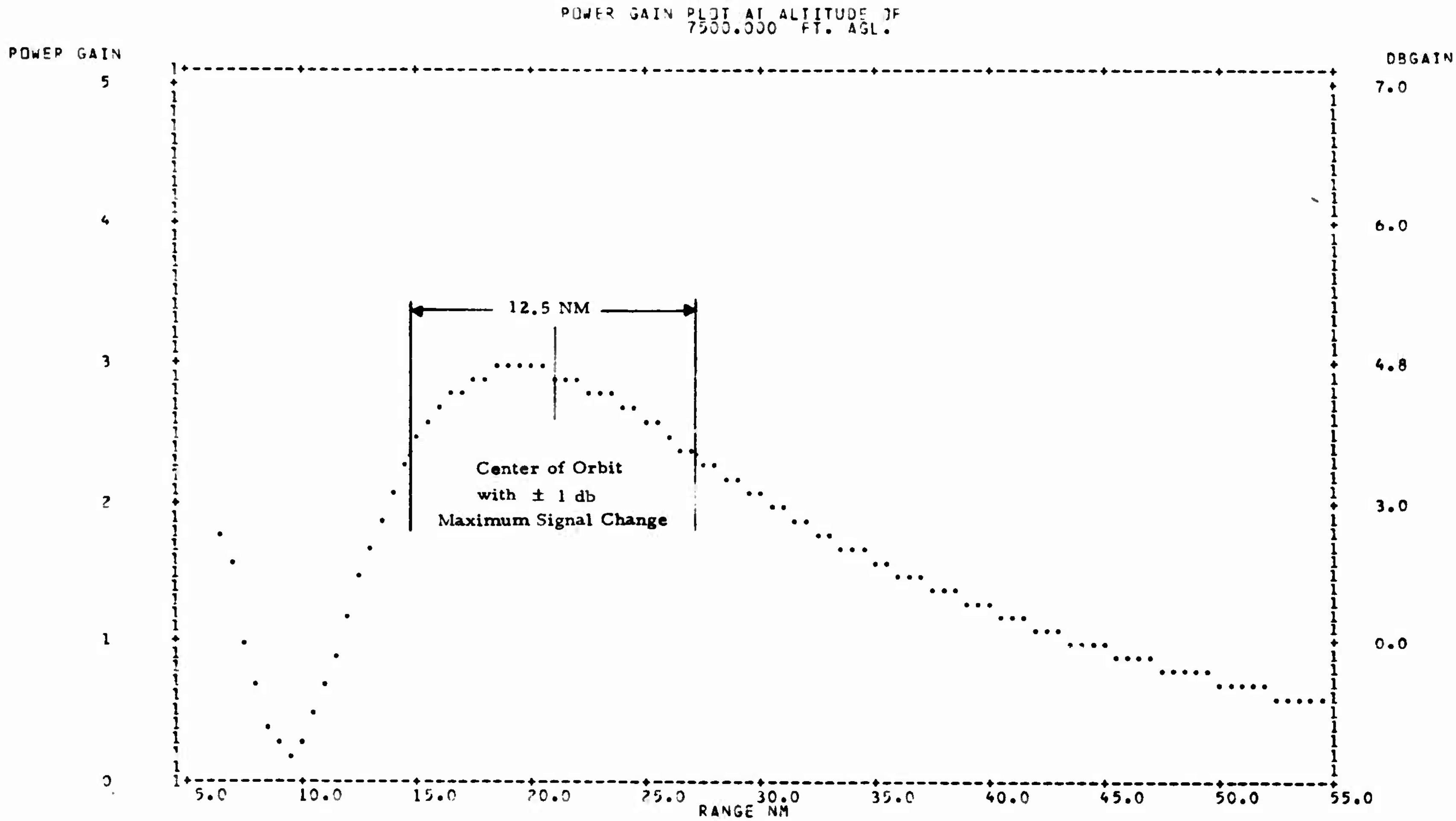
The flight technique which is capable of producing a 360 degree, constant depression angle, antenna pattern in the shortest time is the skidding turn. This technique requires the aircraft to complete a 360 degree turn keeping the wings level. To assist in making the turn, rudder trim and asymmetric power may be used. The location of the center of the turn should be picked to keep the aircraft within a major lobe of the ground antenna (figure 17). As with the other techniques, the areas of cancellation should be avoided to minimize the multipath radiation effects. The diameter of the circle will depend on the capabilities of the aircraft. On previous tests a C-131 flew the skidding turn within an 8 NM circle and an F-15 within 5 NM. Since the objective of this flight technique is to rotate the aircraft about its vertical axis, the actual ground path is of no concern except to insure the aircraft does not enter an area of signal cancellation. To correct for distortion of the measured antenna pattern, the multipath correction option should be used when processing the data. Figures 18 through 21 show a comparison of skidding turn data with and without the multipath correction option.

To properly conduct a skidding turn flight, a map to be used for radar tracking should be marked with concentric circles around the desired orbit center. By using a one inch to 1 NM scale map and 2.5 NM, 5 NM, 10 NM, 15 NM diameter circles, the aircraft can be vectored to a starting point which will minimize the effects of wind drift. The major concern is to keep the aircraft from drifting into a region of cancellation. After the aircraft is vectored to the starting point, the aircraft will be setup into a constant rate skidding turn. Every 15 degrees during the turn, the pilot must call his heading as read off the directional gyro. The heading and IRIG "B" time will be recorded at the ground station for use in the Antenna Radiation Pattern Measurement Program. This program performs a linear time extrapolation to determine the aircraft heading throughout the turn for correlation with radar and signal strength data. With the aircraft in a constant rate turn, the headings can be determined within two degrees using this technique. The major source of error is in reading the directional gyro and recording the proper time.

If the aircraft cannot complete the turn within a 10 NM diameter circle or if the aircraft drifts too close to the ground station, the circle can be flown in segments. Figures 20 and 21 show data collected on an F-15 turn flown in two segments with and without multipath correction.

There are numerous advantages to this type of flight pattern. The main advantage is the short time required to complete a 360 degree antenna pattern. Depending on the capabilities of the aircraft, this turn can take as little as four minutes. Since the time required to complete a pattern is so short, drift will be minimized in the test equipment.

The major disadvantage is the requirement for the aircraft to be forced into the turn with sideslip. The ability of the aircraft to accomplish this depends on the type of aircraft. In some aircraft, this may cause engine fuel starvation due to lateral acceleration.



DISTANCE INTERVAL NM 5. TO 55. ANTENNA HEIGHT FT. 27.0 FREQUENCY MHZ 139.80 POL(0=H, 1=V) 1.00 PERMITTIVITY 5.00 CONDUCTIVITY .00100

CALCULATED INDEX OF REFRACTION SQUARED 5.0000 -.1238 J DISTANCE FR. ANTENNA TO REFLECTION PT. NM. MINIMUM .02 MAXIMUM .26

Figure 17 Location of Skidding Turn

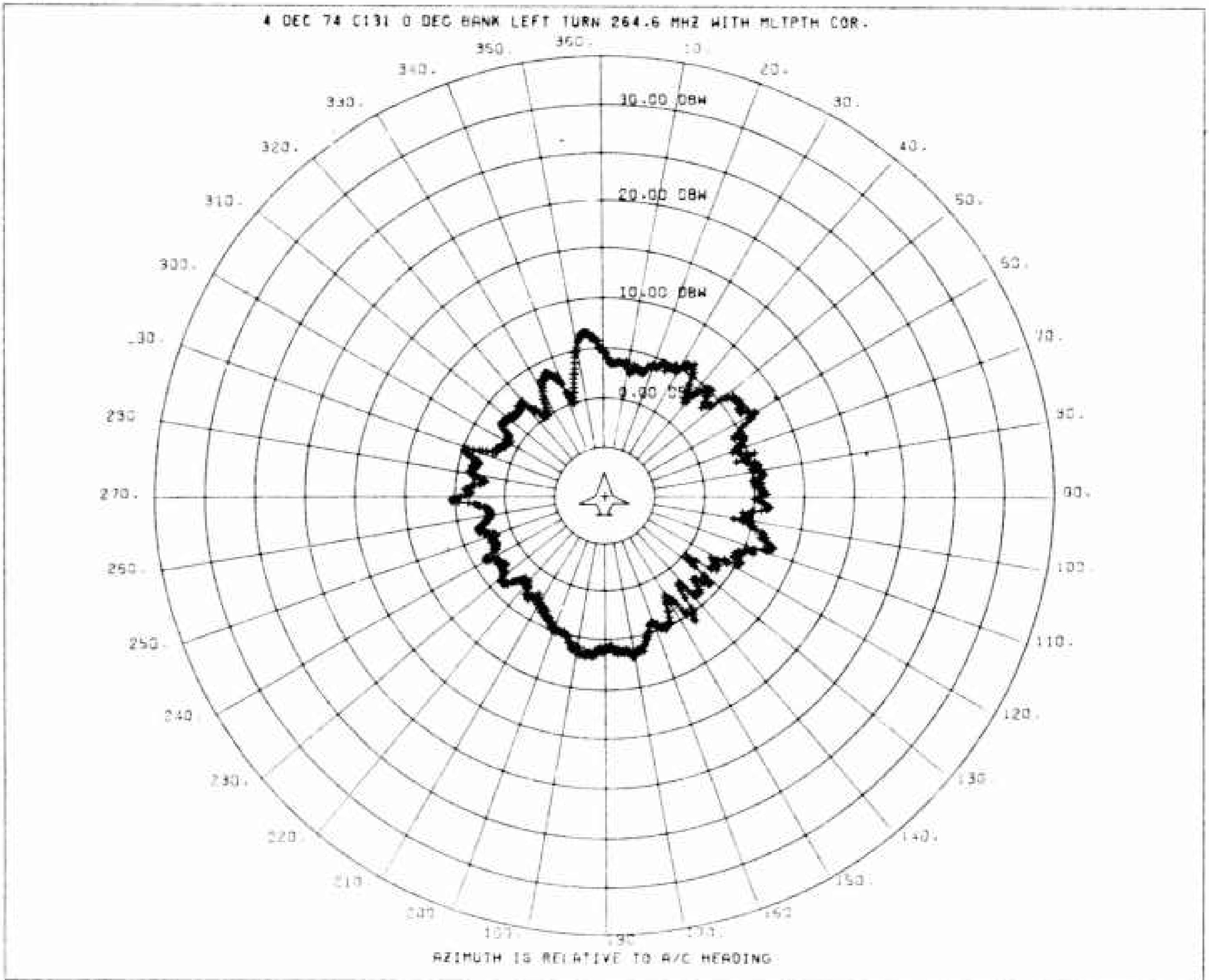


FIGURE 18 SKIDDING TURN ANTENNA PATTERN

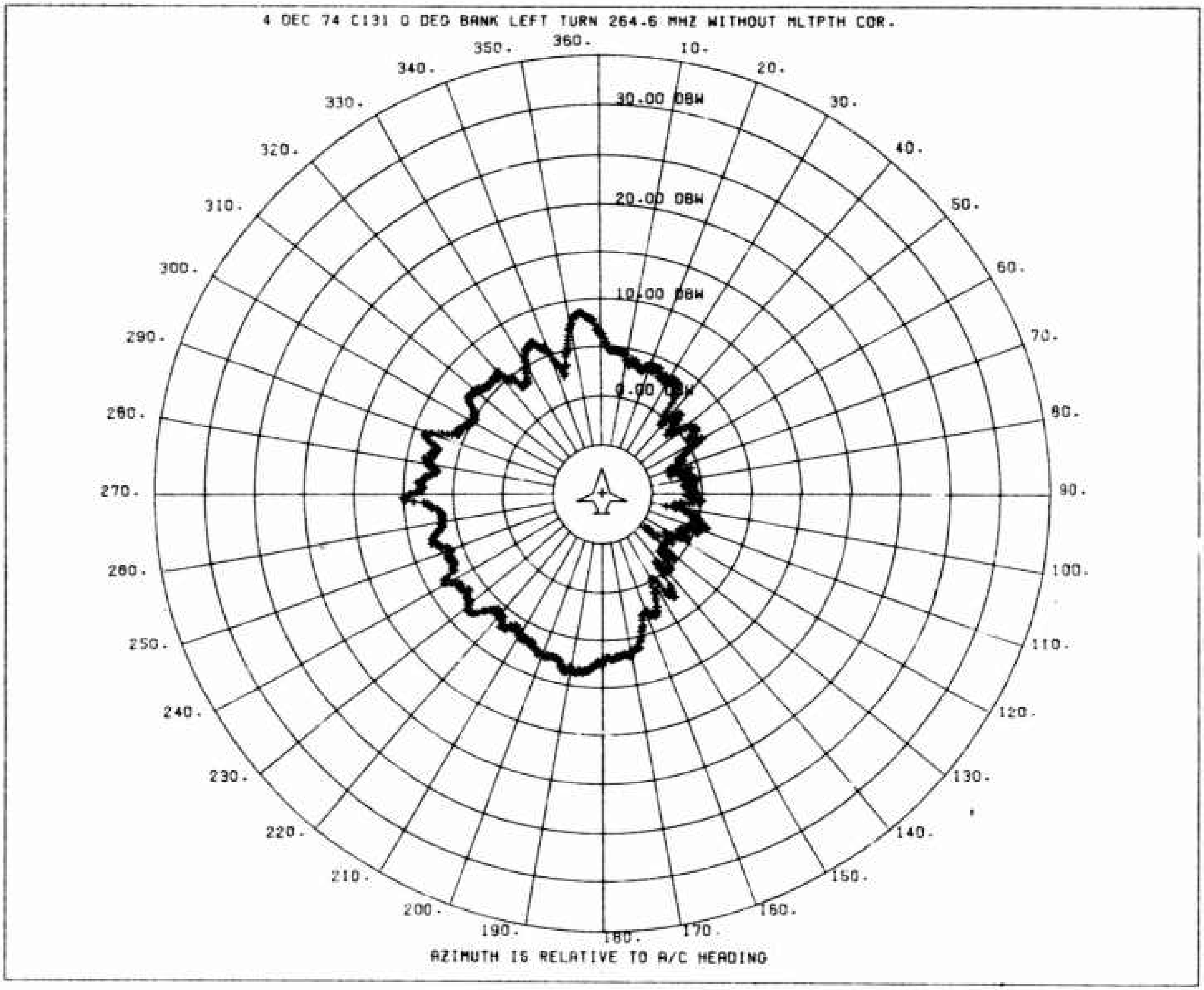


FIGURE 19 SKIDDING TURN ANTENNA PATTERN

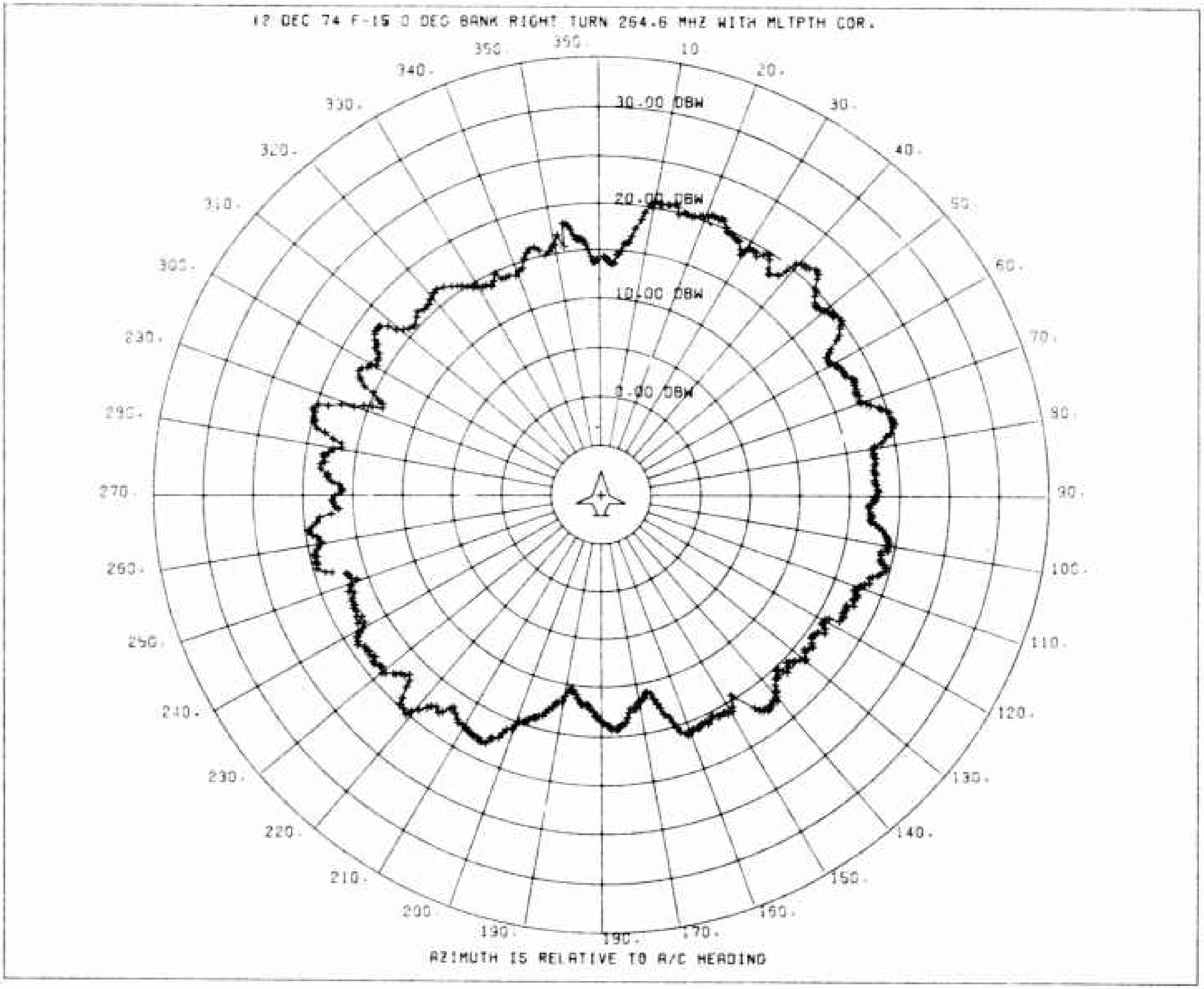


FIGURE 20 SKIDDING TURN ANTENNA PATTERN

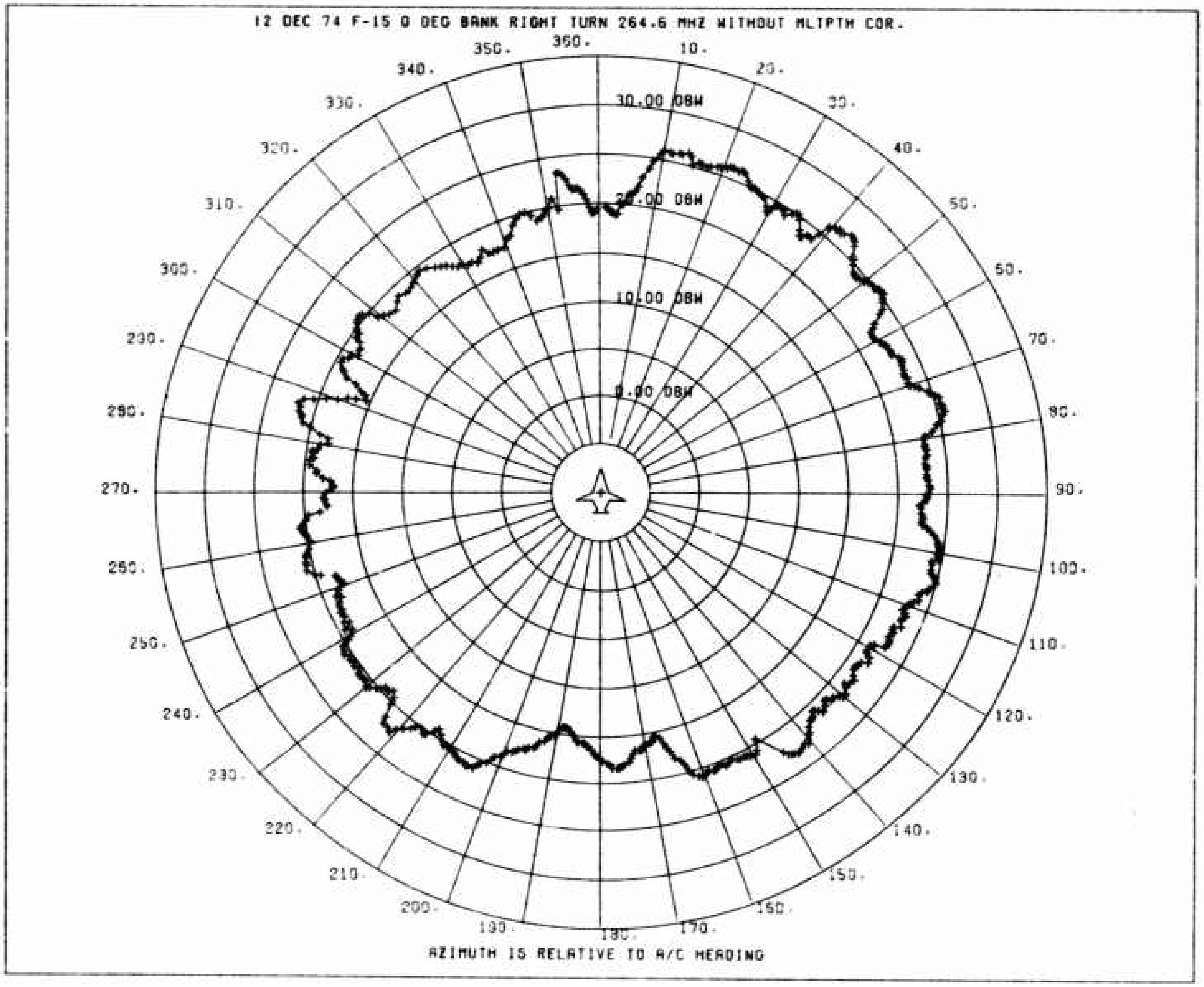


FIGURE 21 SKIDDING TURN ANTENNA PATTERN

BANKED TURNS

Banked turns are flown using the same basic technique as the skidding turns, except the aircraft is placed in a constant bank turn. Once the turn is established the pilot must call the heading at the start and every 15 degrees throughout the turn. The headings and IRIG "B" times should be recorded at the ground station for use in the Antenna Radiation Pattern Measurement Program. The same precautions to avoid the areas of signal cancellation should be taken with this technique as with the skidding turns.

Banked turn orbits produce a series of decaying sine wave depression angles as shown in figure 22. Through the combination of a series of different banked turns, partial upper and lower hemispheric patterns can be measured. The actual depression angles covered are a function of bank angle, range, altitude, and orbit diameter.

Since some model antenna radiation patterns are measured as circular cuts, the banked turn can be used to flight measure the same patterns.

A disadvantage of the banked turn technique is that it does not produce conical antenna patterns which are the patterns normally of concern. Additionally, due to the high turn rate in a banked turn, the number of averaged 0.5 second data samples per pattern are reduced. Where a skidding turn may produce up to five samples per degree azimuth, the banked turn may produce less than three data points per degree.

POLYGON TURN

The polygon turn is an effective technique to measure an antenna pattern in a short period of time; yet, avoiding the skidding turn. This technique can easily produce 72 data points per 360 degrees which creates a reasonable representation of the actual antenna pattern. Figures 23 and 24 show a comparison of an antenna pattern measured with a polygon and a skidding turn.

To fly a polygon pattern, the aircraft is required to be at a wings level attitude when the heading is called on each leg. Once the heading is called a banked turn should be executed as quickly as possible to change the heading approximately five degrees. This process should be repeated until a 360 degree circle has been completed with each called heading and IRIG "B" time recorded.

The technique required to radar vector the aircraft to the proper starting point is the same as for the skidding turns. The starting point should be such that the required diameter of the turn, in conjunction with the drift due to wind, does not cause the aircraft to fly into an area of cancellation. The diameter of a polygon flown by a C-131 on a previous test was 12 NM.

This flight technique is useful in the event the aircraft cannot be turned in a wings-level-skid. Since most, if not all, airplanes can fly a skidding turn this technique will not normally be used.

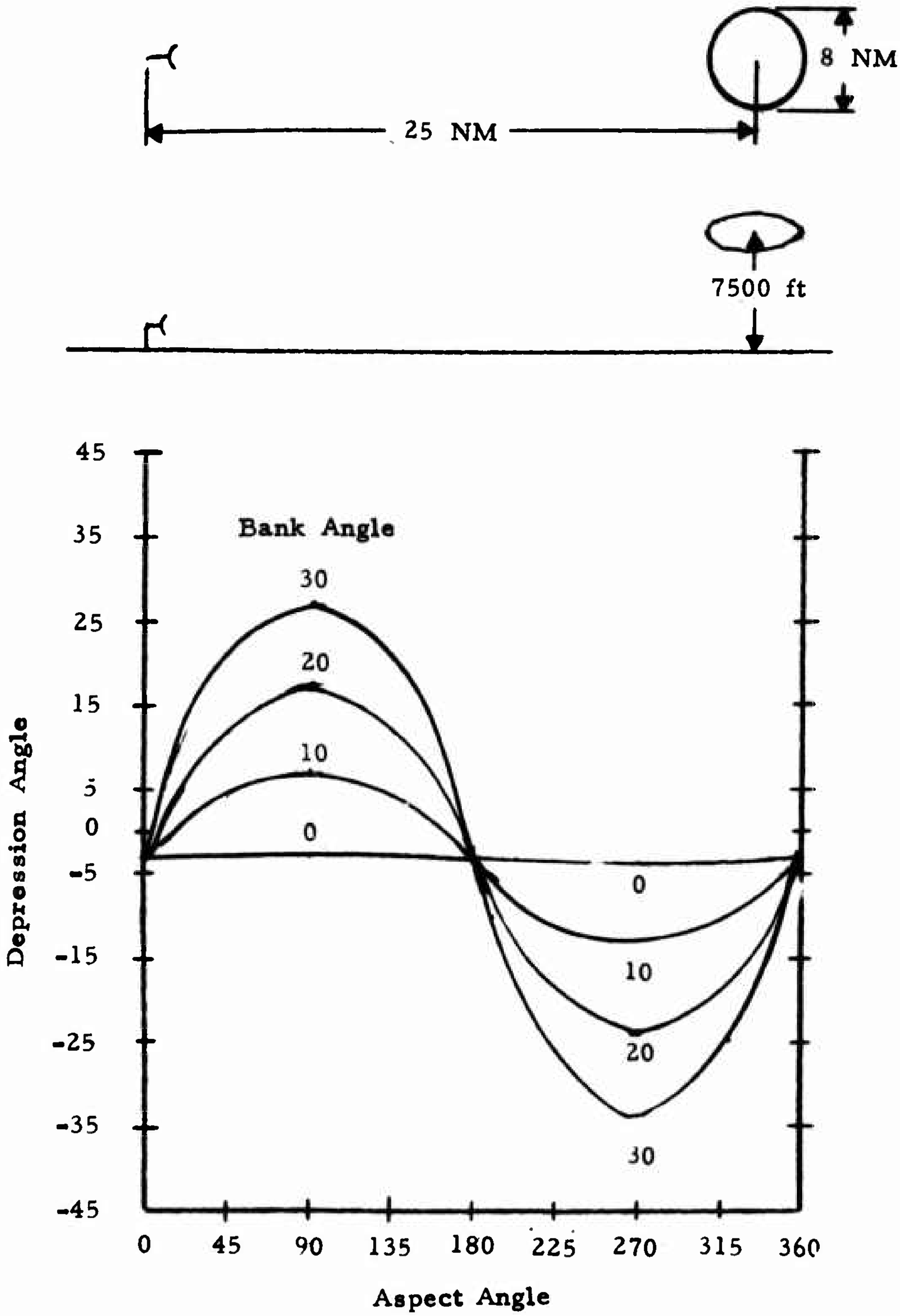


Figure 22 Orbit Turn Depression Angle Coverage

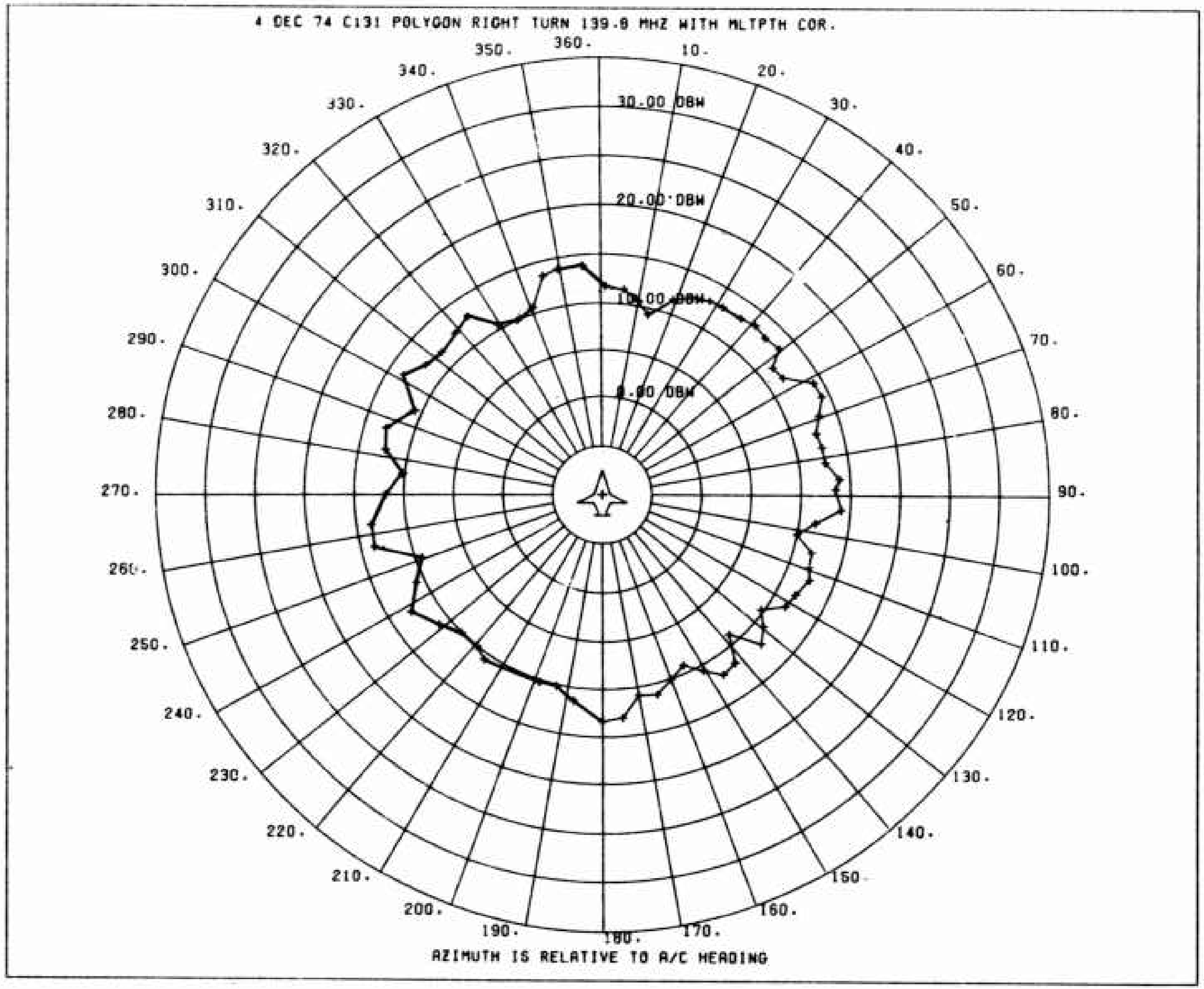


FIGURE 23 POLYGON ANTENNA PATTERN

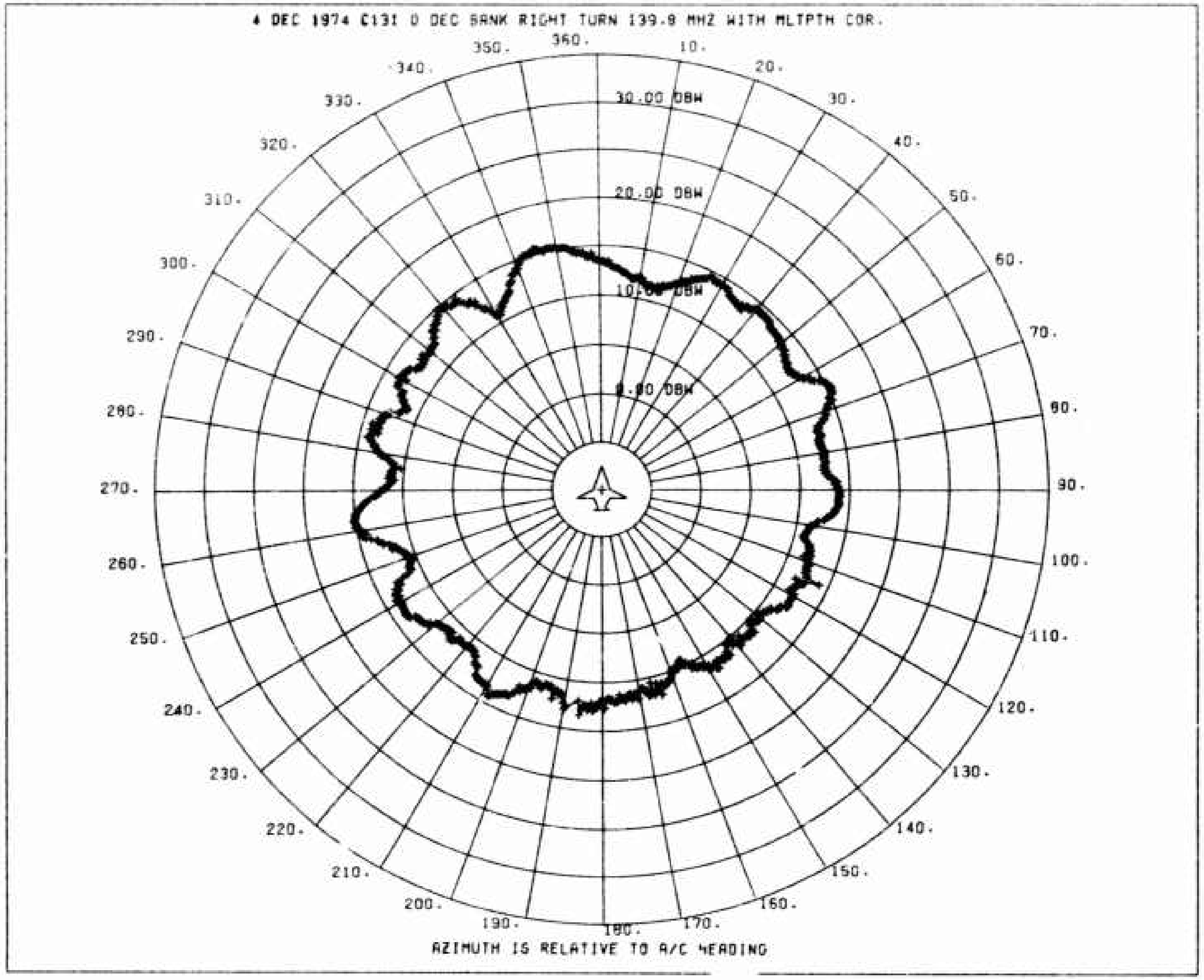


FIGURE 24 SKIDDING TURN ANTENNA PATTERN

The main disadvantage is the large diameter of the flight path. Since only half the flight time is spent in a turn, the pattern will tend to be large. This may require the polygon to be flown in segments.

TEST PLANNING

ADVANCED PLANNING

Advanced planning for a test of an aircraft antenna radiation pattern should determine the facilities to be used, the antennas to be measured, the flight technique to use, and estimates of flight time and computer time. With the determination of these factors the initial test planning can be finalized.

The first major item to be determined in planning a test is which facility to use. There are three facilities which can be used to perform these tests. The choice of the facility will be made on the data requirements. For the measurement of antenna patterns between 100 MHz and 400 MHz, building 275 at the South Base should be used. As planned, a facility will be developed at this building which will be capable of measuring six antenna patterns between 100 MHz and 400 MHz simultaneously. For pattern measurements in the 1.435-1.540 GHz or 2.2-2.3 GHz range the receivers and tracking antenna located at the TM site, building 5780, can be used. This equipment should be used in the same manner as the South Base facility. For tests which involve frequency ranges unavailable at Edwards AFB or for tests which involve a large number of antennas, the facility located at Griffiss AFB, New York should be considered.

The major dynamic measurement facility of aircraft antennas is the Precision Antenna Measurement System (PAMS) of the Rome Air Development Center (RADC) at Griffiss AFB. This facility is located at the Verona Test Range, 18 miles south of Griffiss AFB. The PAMS facility is capable of measuring 12 CW, AM, FM, or pulsed signals simultaneously on any frequency from 0.1 GHz to 18 GHz. This system is also capable of measuring integrated power spectral density between pairs of frequencies and radar cross sectional areas. Through the use of tracking receiving antennas, tracking radar, and onboard aircraft attitude recorders, the PAMS facility is capable of being used with any type of flight pattern. If the frequencies to be measured are above 1 GHz and are not between 1.435-1.54 GHz or 2.2-2.3 GHZ, PAMS should be used and appendix A should be referenced for an additional discussion on PAMS.

The flight pattern to be flown will depend upon the type of data required and the capabilities of the aircraft. For most tests, a conical antenna pattern will be desired at a low depression angle (-5 degrees). In this case the skidding turns will produce the best antenna patterns in the shortest flight time. For other types of data requirements, different flight techniques may be used. If high depression angles are required, banked turns or parallel flybys should be used. An estimate of the depression angle covered at different altitudes and ranges can be found from figures 25 and 26.

NOTE: Earth Radius = 3436.99 NM, 1 NM = 6076.1 FT
K = 4/3

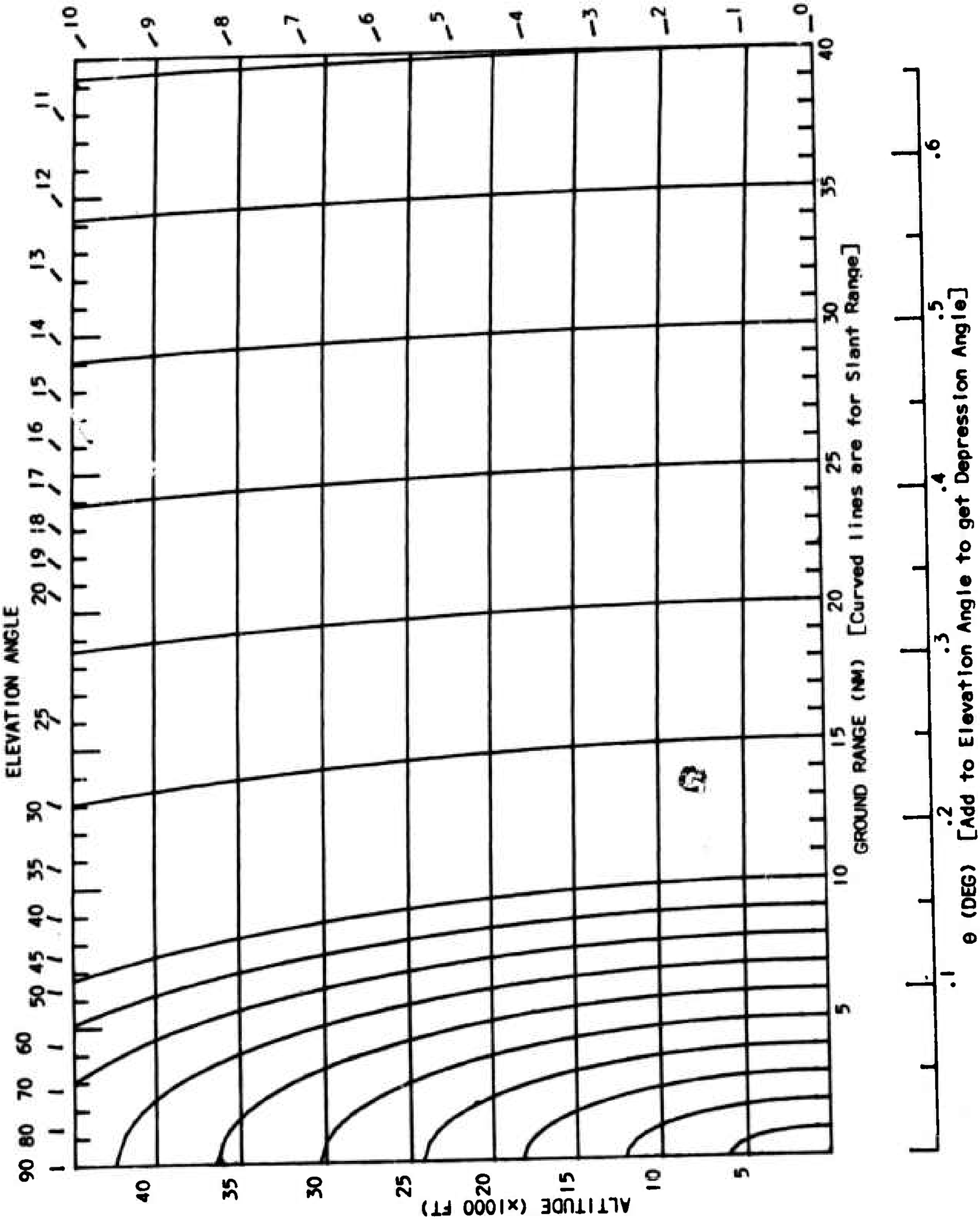
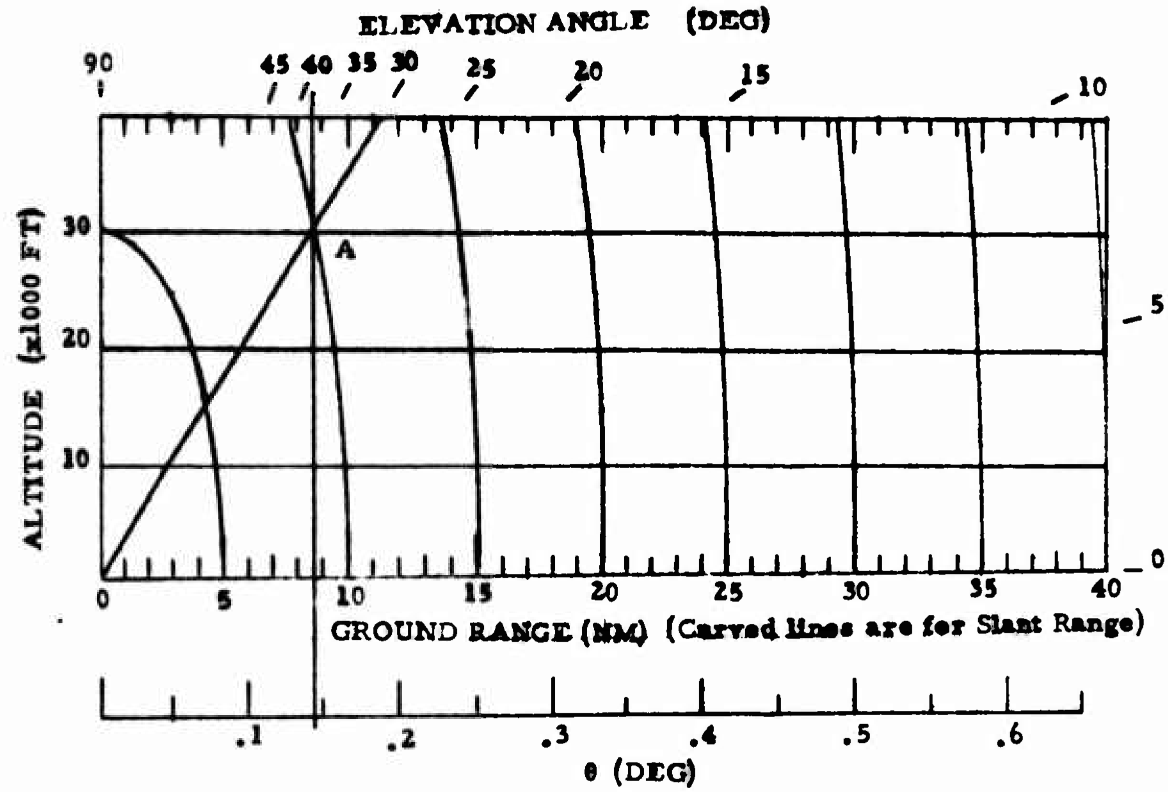


Figure 25 Vertical Coverage Chart



The correct values for point A are:

Ground Range	8.65	NM
Slant Range	10	NM
Elevation Angle	30.0	°
θ	0.14	°
Altitude	30,430	FT
Depression Angle	30.14	°

Given any two of the first five variables, the others can be found using the chart.

Given the Depression Angle and any one of the first four variables, the others can be found using the chart.

For ranges greater than 40 NM use the other Vertical Coverage Chart.

Figure 25 (Continued)

NOTE: Earth Radius = 3436.99 NM, 1 NM = 6076.1 FT
K = 4/3
Ground Range approaches Slant Range for ranges greater than 40 NM

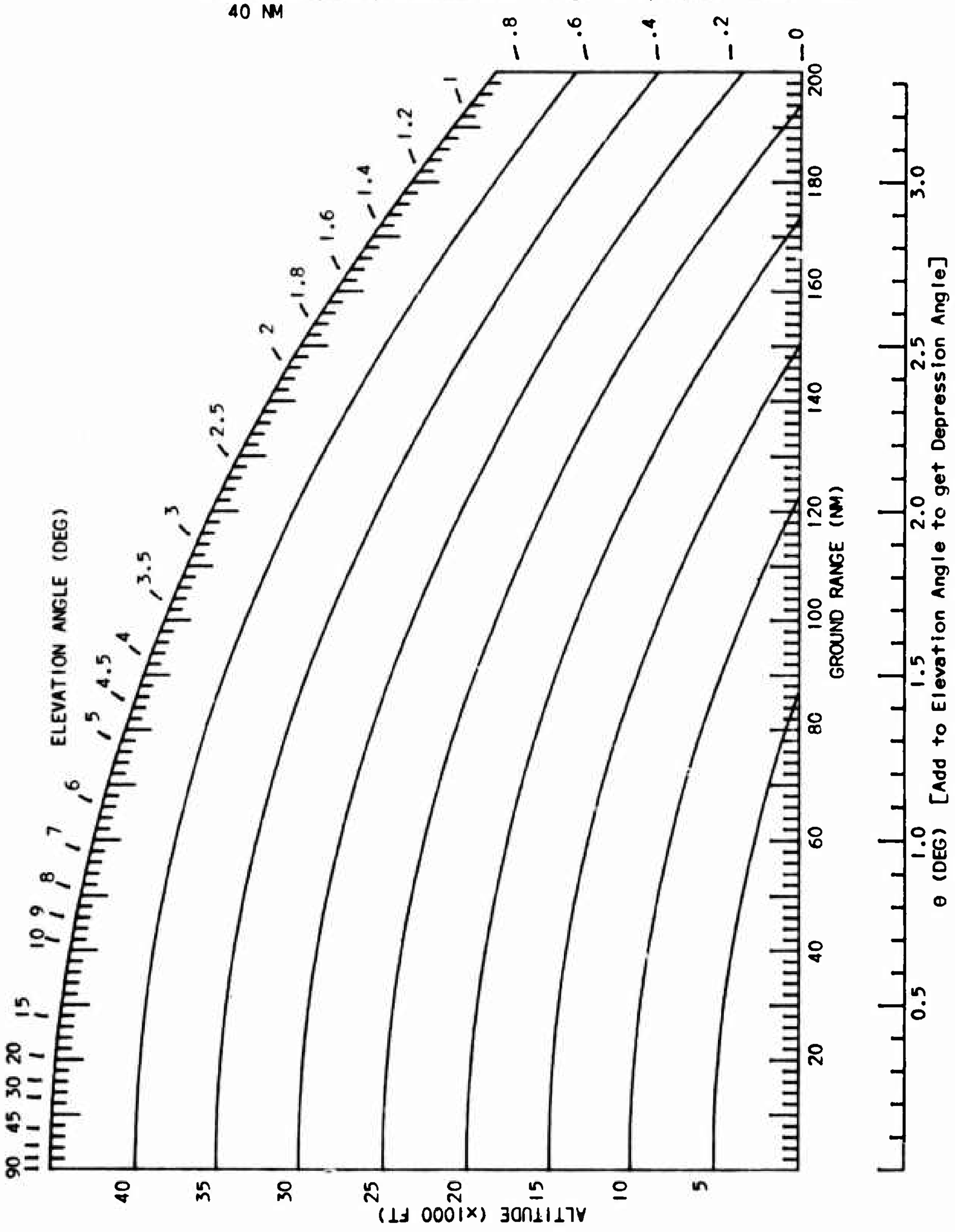
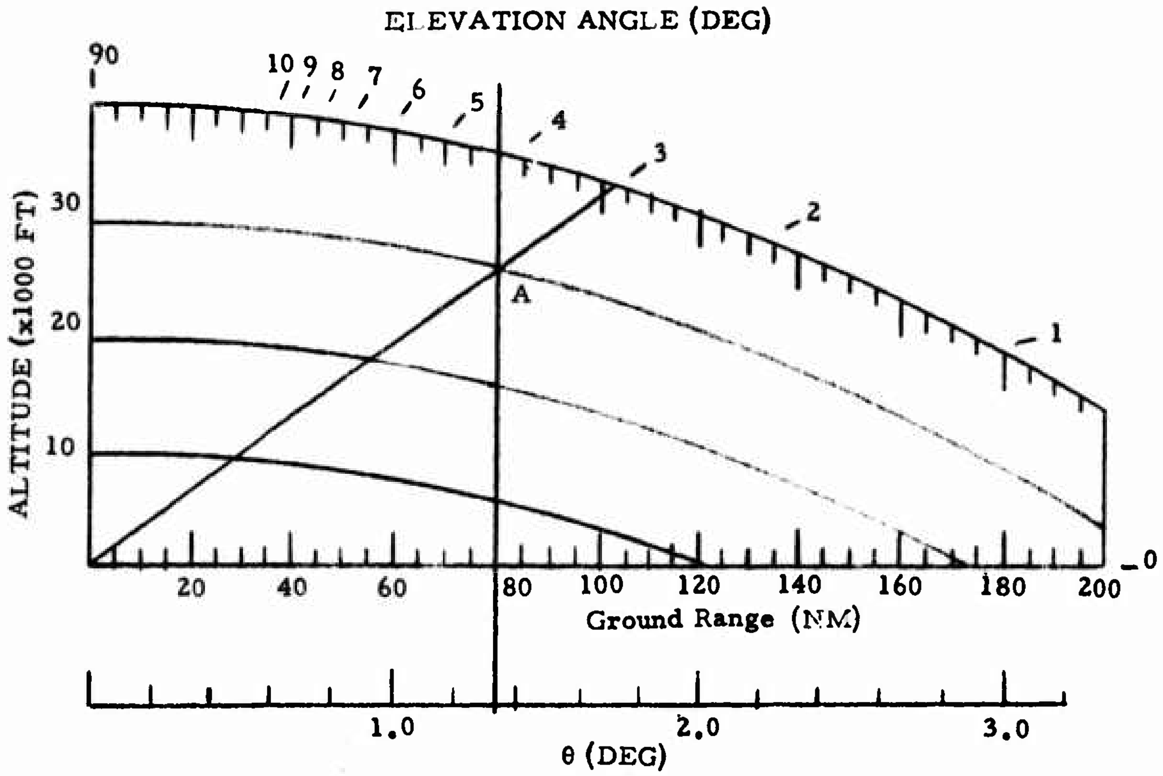


Figure 26 Vertical Coverage Chart



The correct values for point A are:

Ground Range	80	NM
Slant Range	80.2	NM
Elevation Angle	3.0	°
Θ	1.34	°
Altitude	29,747	FT
Depression Angle	4.34	°

Given any two of the first five variables, the others can be found using the chart.

Given the Depression Angle and any one of the first four variables, the others can be found using the chart.

For Ground Ranges greater than 40 NM, the Slant Range is within 0.8 NM of that range.

For ranges less than 40 NM use the other Vertical Coverage Chart.

Figure 26 (Continued)

To estimate the flight time requirement, the number of flight patterns flown must be determined. Since the test may require antenna patterns with various aircraft configurations, the minimum number of flights required must be determined. Flying multiple configurations on each flight and measuring multiple frequencies will reduce the total flight time required to complete the test. Therefore, one flight can produce antenna patterns with the landing gear up and down and flaps extended and retracted.

If the multipath radiation is to be eliminated with the Antenna Radiation Prediction Measurement Program, data collected on radial flights will optimize the calculation. This data can be used if the antenna pattern is expected to be essentially constant from 0 to -10 degrees depression angle at the nose or tail of the aircraft.

The total flight time for each flight can be estimated by summing the following times: (1) time to fly radial, (2) time to fly each orbit (or other patterns), and (3) time to vector aircraft to start of patterns (five minutes x number of patterns).

DETAILED PLANNING

After advanced planning has been completed and flight time estimates provided to the Project Engineer, the Systems Engineer should begin the detailed planning of the test. This section will present the test preparation, data collection, and data reduction requirements for the detailed planning phase.

Test Preparation:

In preparing for a test, the Systems Engineer should first review all existing pertinent data on the antenna system being evaluated. Previous model patterns or previous dynamically measured patterns should be reviewed to locate specific antenna patterns which may be of significant interest. This would be any large holes which may be present or any unexpected holes in the pattern which may require special emphasis. The physical location of the antenna on the aircraft should be reviewed to determine the potential effects the aircraft structure and external stores may have on the antenna pattern. Holes in patterns may be caused by shielding of the antenna or reradiation by the aircraft structure. Pilot reports of unexpected loss of communications are one means to locate potential holes in antenna patterns. These reports can provide insight into deficiencies of antenna systems.

Planning the tests will involve estimating the amount of support to be required by Technical Services (AFFTC/DOET). This support will consist of CDC 6500 computer time, Calcomp plotter time, VHF/UHF Antenna Radiation Pattern Measurement Facility (building 275), FPS-16 radar tracking (SPORT) including radar recording, radar tapes created by AFFTC/DOETDA (Data Analysis Section), and digitized signal tape created by DOETDD (Digital Data Processing Section).

Estimates of the time required for each of the above organizations can be determined with the following equations:

Computer CPU time in minutes (T_c)

$$T_c = (\text{Flight time in hours})(\text{number of frequencies recorded}) \times (2) + (\text{number of plots to be produced}) \times (.2)$$

Calcomp plotter time in minutes (T_p)

$$T_p = (\text{Number of plots to be produced}) \times (2.5)$$

Time estimates for the radar tapes and digitized signal tape will be equal to the flight test time. The tracking radar time estimates will be equal to the flight time plus 15 minutes per flight to allow time for the radar to initiate tracking.

Time estimates for the VHF/UHF Antenna Radiation Pattern Measurement Facility will be equal to the flight time plus three hours per flight. This will allow two hours before the flight for system warm-up and pre-calibration. One hour is allowed after the flight for post-calibration.

Frequencies must be assigned to the project from Frequency Management (1925 COMM Sq/DCXF). Each frequency must be assigned to the test project, since any interference from other transmitters will create erroneous signal strengths. One communication frequency must also be assigned which cannot be jointly used with other projects. Since the aircraft will be radar vectored and the pilot will be calling headings, interference from other projects will cause loss of data and difficulty in radar vectoring. If the aircraft does not have a second communication radio which can be used for communicating with RAPCON, control of the aircraft can be maintained by requesting RAPCON to monitor the test communication frequency.

After the test has been planned in detail, the System Engineer should prepare a Test Information Sheet (TIS), AFFTC Form 0-128, for inclusion in the final test plan. This form should be completed according to the Systems Engineering Handbook, page I-II-6. This should be accomplished at least two weeks prior to the test.

A test card (figure 27) should then be prepared. This card should contain information which will be required by all test participants and be distributed at the pilot's briefing prior to the flight.

Data Collection:

The data collected during a test will consist of manually recorded data by the Systems Engineer and magnetic tape recording of signal strength and radar positioning. The data recorded by the Systems Engineer will consist of transmitter power, before and after each flight, pre- and post-calibration information, flight times, heading information, and signal tape identification information.

ANTENNA PATTERN EVALUATION

JON 998300

OPS 336-77

A/C - F-15 No. 20113

A/C Call Sign - Eagle 11

Radar Call Sign - SPORT

South Base Call Sign - BARRIER

Communication Freq - 315.9 MHz

Takeoff - 0800 12 Dec 1974

Test Altitude 10,000 MSL

Test Freqs - 264.6MHz

139.8 MHz

TEST SEQUENCE

1. Contact SPORT to initiate radar tracking
2. Contact BARRIER for test freq ID
3. Fly outbound radial
4. Fly right skidding turn
5. Repeat 4
6. Repeat 4
7. Fly inbound radial
8. Terminate test

Figure 27 Sample Test Card

The power delivered to each test antenna at each test frequency should be measured before and after each flight. This measurement should be made on the aircraft with a calibrated Radio Frequency (RF) power meter. These measurements will indicate if the transmitters are providing constant power to the antenna. Additionally, the measured power can be compared with the antenna patterns to show gain or loss from the isotropy.

The power measurement should be in dbw and the line losses in db.* If power is measured in dbm or watts, it can be converted to dbw with the following equations:

$$\mathrm{dbw} = 10 \log P_w - \mathrm{db}_{(L)}$$

or

$$\mathrm{dbw} = \mathrm{dbm} - 30 - \mathrm{db}_{(L)}$$

where

dbw = power to antenna in db above a watt

P_w = power measured in watts

dbm = power measured in db above a milliwatt

$\mathrm{db}_{(L)}$ = line loss in db between the power measurement point and the antenna

One of the most critical tasks of measuring antenna patterns is the calibration of the receivers. Since the final data will depend upon the accuracy of the calibration points, care must be taken to insure the points are valid. This will involve insuring the calibration equipment is operating correctly, the correct signal strengths are used, and connecting cables are in good condition.

In calibrating the receivers the object is to place a known signal, from a calibrated RF generator, at the input terminals to the receiver. This will produce a signal which is recorded on the FM tape and can be correlated with the known signal with time.

To accomplish the calibration, an RF power meter is connected to the RF signal generator in place of the receiver and the output of the signal generator is calibrated. The power meter is removed and the RF generator is connected to the input terminals of the receiver. The output attenuator of the signal generator is reduced in 5 db steps for each calibration point with the signal to the receiver and time recorded for use by the data reduction program.

* Note: Power is normally measured in dbw except for very low power levels (typically receiver input terminals) when dbm is normally used.

Normally the calibration points and the signal input to the receiver should range from approximately -50 dbm to -100 dbm. The actual range of the calibration can be changed once the received signal strength is known from test flights.

For each flight pattern flown the aircraft magnetic heading and IRIG "B" time must be recorded by the Systems Engineer as called by the pilot. This data will be entered in the Antenna Radiation Pattern Measurement Program for final processing of the data. The headings may also be recorded on the radar plot board for future reference.

Data Processing:

Processing of data collected during the test will begin with the creation of a digital signal tape and radar tape. These tapes provide the strength of each signal recorded and the location of the aircraft relative to the receiving antenna for use by ADAP and ARPMP.

Requests for the creation of the radar tapes are made through the Data Analysis Section (AFFTC/DOETDA) by submitting the Radar/ Postflight Processing Request (figure 28). The reference point for the processing of the radar data should be the location of the receiving antenna.

Requests for digitizing the FM signal tape are made through the Digital Data Processing Section (AFFTC/DOETDD) by submitting the Digitizing Request (figure 29). When digitizing the tape, care must be taken to insure the data is associated with the correct source number (see appendix B). To insure the correct data is used by ARPMP, the frequency of the measured signal should be included in the source identification (DECOM) card used in digitizing the signal tape (see DOETDD personnel). The contents of this card are recorded on the digitized tape and printed by ARPMP. To improve the resolution of the signal strength data, the signals of interest should be expanded to upper and lower band edge of the data channel. The use of a 6 Hz lowpass filter may be used to reduce the noise content of the data.

Once the radar and signal digital tapes are created, the data may be reduced and plotted using the data reduction programs ARPMP and ADAP. The coding of the proper computer punch cards to accomplish this are found in appendix B and C. Through the use of these programs the final plots can be produced.

DATA ANALYSIS

Analysis of antenna pattern data will consist primarily of analyzing the location and significance of holes found in the antenna pattern. Since empirically measured data is never exact, some errors are to be expected in the measured antenna pattern.

Figures 30 and 31 show a comparison of two measurements of the same antenna pattern. These figures show that, even though the

RADAR/POST-FLIGHT PROCESSING

JON NUMBER 998300

AIRCRAFT---------------------TAIL NUMBER---113--------------------

FLIGHT NUMBER---8---- ------

FLIGHT DATE---12 Dec 74----

OPS NO.---346-08------------

REFERENCE POINT(INCLUDING AXIS REFERENCE)---34°53′48.6″ North Lat, 117°51′42″ West Long, 2275.7′ MSL

Location of receiving antenna at South Base

TYPE OF DATA REQUIRED:

STANDARD--X-----------------

N.NASA-----------------------

OLD NASA---------------------

WEATHER REQUIRED: YES----NO-X-

DATA SELECTION:

1. ALL DATA BETWEEN DATA ON AND DATA OFF--X-----
2. DATA BEFORE AND AFTER TONES-----------------
   A. NO. SECS. BEFORE-----------------------
   B. NO. SECS. AFTER------------------------

NUMBER OF SAMPLES PER SEC. REQUIRED----10-----------

SPECIAL INSTRUCTIONS:

use output Tape No. 8676

DIGITAL OUTPUT TAPE YES--X---NO-----

ENGINEER RESPONSIBLE---John Doe------PHONE--72475--------

Figure 28 Sample Request for Radar Tape Processing

PROJ OFFICER John Doe	PREFLIGHT 20-80 PCT CAL/NULL TIMES	JON 998300
PHONE 72475	ON ____ OFF ____ FILE ____	FLT DATE 12 Dec 74
TYPE OF FLIGHT Antenna Patterns	POSTFLIGHT 20-80 PCT CAL/NULL TIMES	TIME 1700
	ON ____ OFF ____ FILE ____	PROJ F-15
TAPE SPEED, 15 IPS	DATA (OR EVENT) TIMES	TAIL NO 113
REWOUND YES X NO ____	ON 165430 OFF 192200 FILE ____	FLT NO 346-08
TRACK ASSIGNMENTS	ON ____ OFF ____ FILE ____	OP NO ____
1 Audio	ON ____ OFF ____ FILE ____	TEST NO ____
2 IRIG "E"	ON ____ OFF ____ FILE ____	ANALOG TAPE NOS 3221-A
3 Data (5.4 KHz and 14.5 KHz)	ON ____ OFF ____ FILE ____	____
4 ____	ON ____ OFF ____ FILE ____	____
5 ____	ON ____ OFF ____ FILE ____	____
6 ____	ON ____ OFF ____ FILE ____	____
7 ____	ON ____ OFF ____ FILE ____	
8 ____	ON ____ OFF ____ FILE ____	
9 ____	ON ____ OFF ____ FILE ____	____
10 ____	ON ____ OFF ____ FILE ____	OUT ____
11 IRIG "B" Direct	ON ____ OFF ____ FILE ____	____
12 IRIG "B" FM 54 KHz	ON ____ OFF ____ FILE ____	IN ____
13 25 KHz Ref	ON ____ OFF ____ FILE ____	
14 ____	ON ____ OFF ____ FILE ____	TIME ____
REVISIONS	ON ____ OFF ____ FILE ____	
____	ON ____ OFF ____ FILE ____	DIGITAL TAPE NOS ____
____	ON ____ OFF ____ FILE ____	____
____	ON ____ OFF ____ FILE ____	____
____	ON ____ OFF ____ FILE ____	____
____	ON ____ OFF ____ FILE ____	____

Note: 5.4 KHz Data will be Data Cal record #1 and 14.5 KHz Data will be Data Cal record #2
Decom card for Data Cal record #1 specify "139.8 MHz" and for Data Cal record #2 "264.6 MHz"
Digitize tape at 10 samples per seconds

Figure 29 Sample Request for Signal Tape Processing

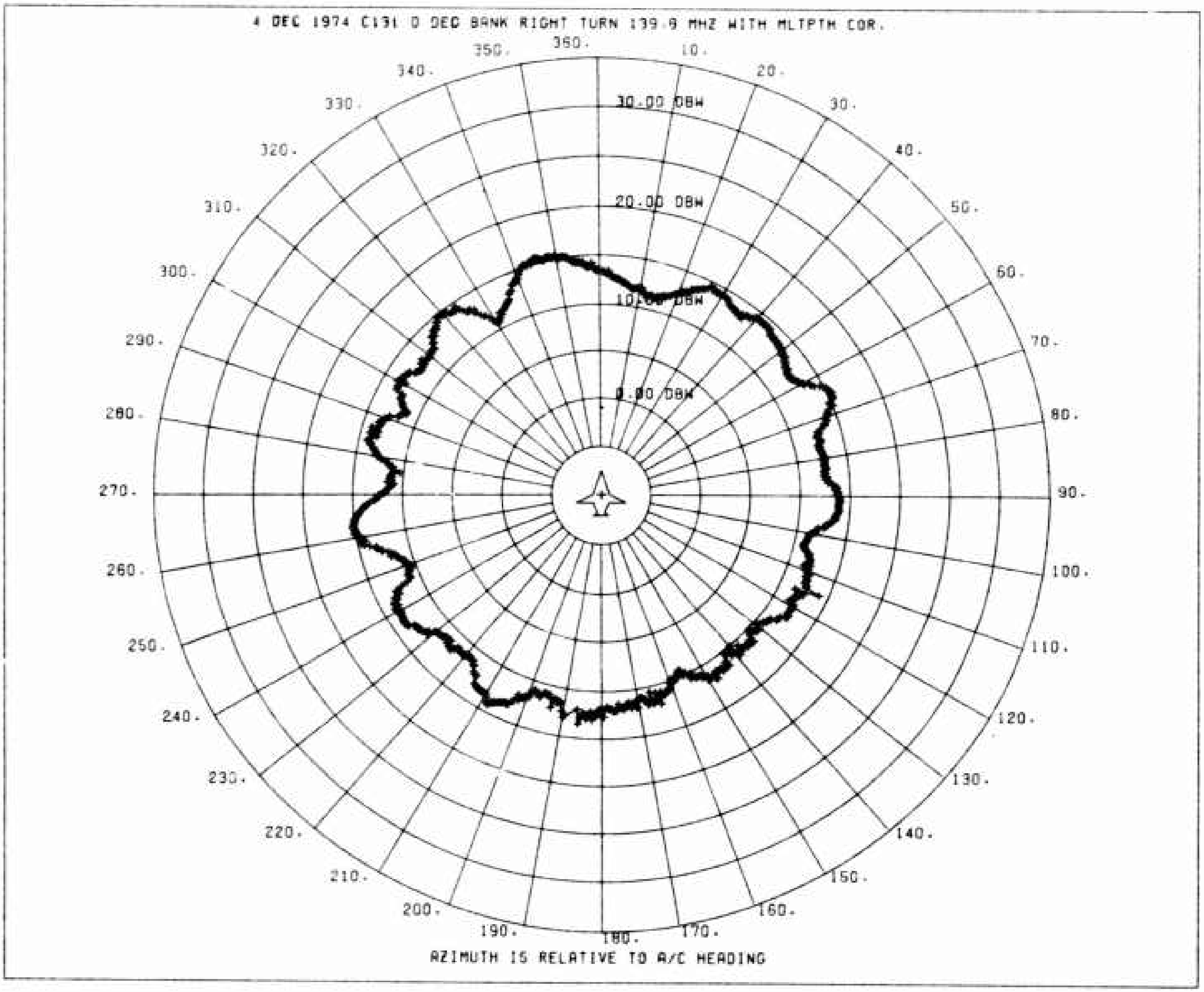


FIGURE 30 SKIDDING TURN ANTENNA PATTERN

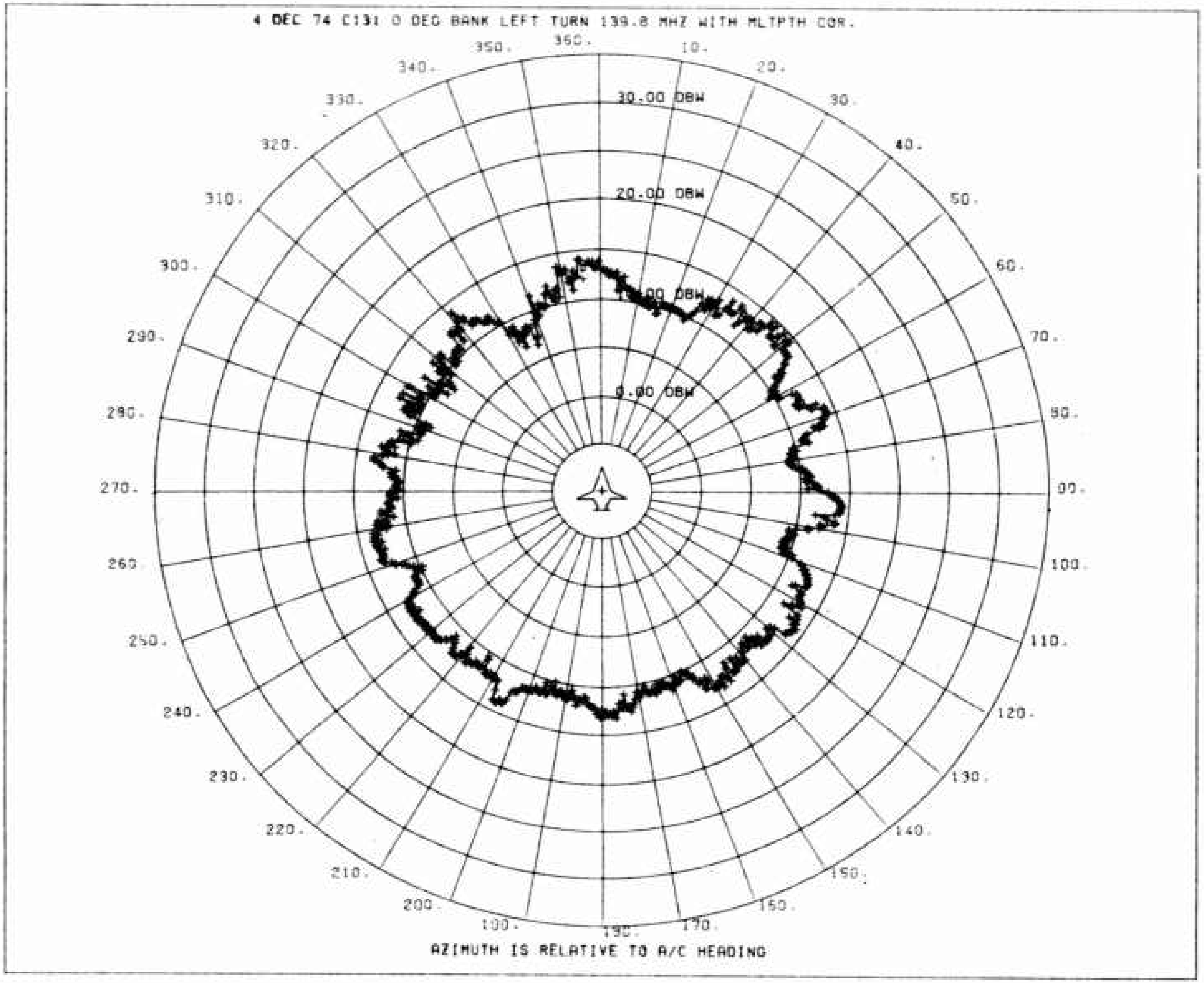


FIGURE 31 SKIDDING TURN ANTENNA PATTERN

measured patterns are not identical, the basic characteristics of each pattern are the same. The repeatability of these patterns are as close as can be reasonably expected.

The significance of holes in antenna patterns can be seen through an analysis of the one way range equation for electromagnetic radiation propagation.

$$P_R = P_T + G_R + G_T + G_M - L - 20 \log R_{NM} - 20 \log F_{MHz} - 7.8$$

P_R = power to receiver in dbm

P_T = output power of transmitter in dbw

G_R = gain of receiving antenna in db

G_T = gain of transmitting antenna in db

G_M = gain due to multipath radiation in db

L = sum of all line losses in transmitting and receiving antennas in db

R_{NM} = range to aircraft in NM

F_{MHz} = frequency of signal in MHz

By assuming values for the minimum discernible signal, gains of the antenna, and line loss; the effect of holes in the antenna pattern can be seen on the usable range of the transmitter. For a comparison the following values are assumed: P_R = -95 dbm, P_T = 30w = 14.8 dbw, G_R = 0 db, G_M = 0 dbm, L = 8 db, F_{MHz} = 264.0.

Figure 32 shows the effect of a hole in the pattern of an omnidirectional antenna on the maximum usable range of the transmitter. For each 10 db loss the maximum usable range is reduced by a factor of 1/3.2. Since most transmissions occur within 100 NM, a 6 db to 10 db loss will be insignificant. Losses greater than this can significantly degrade the capabilities of the transmitter and when combined with multipath cancellation can result in complete loss of communications.

The final analysis of antenna patterns of omni-antennas must consider the location, magnitude, causes of deviations from the isotropic level, and MIL SPEC requirements. For example, a 20 db loss due to landing gear extension may be acceptable but a 10 db loss due to external stores may not be acceptable. In evaluating the acceptable losses, the use of the aircraft in the particular configuration should be considered.

REPORTS

The Systems Engineer, responsible for conducting antenna pattern tests, will be required to prepare progress reports, a final report, and

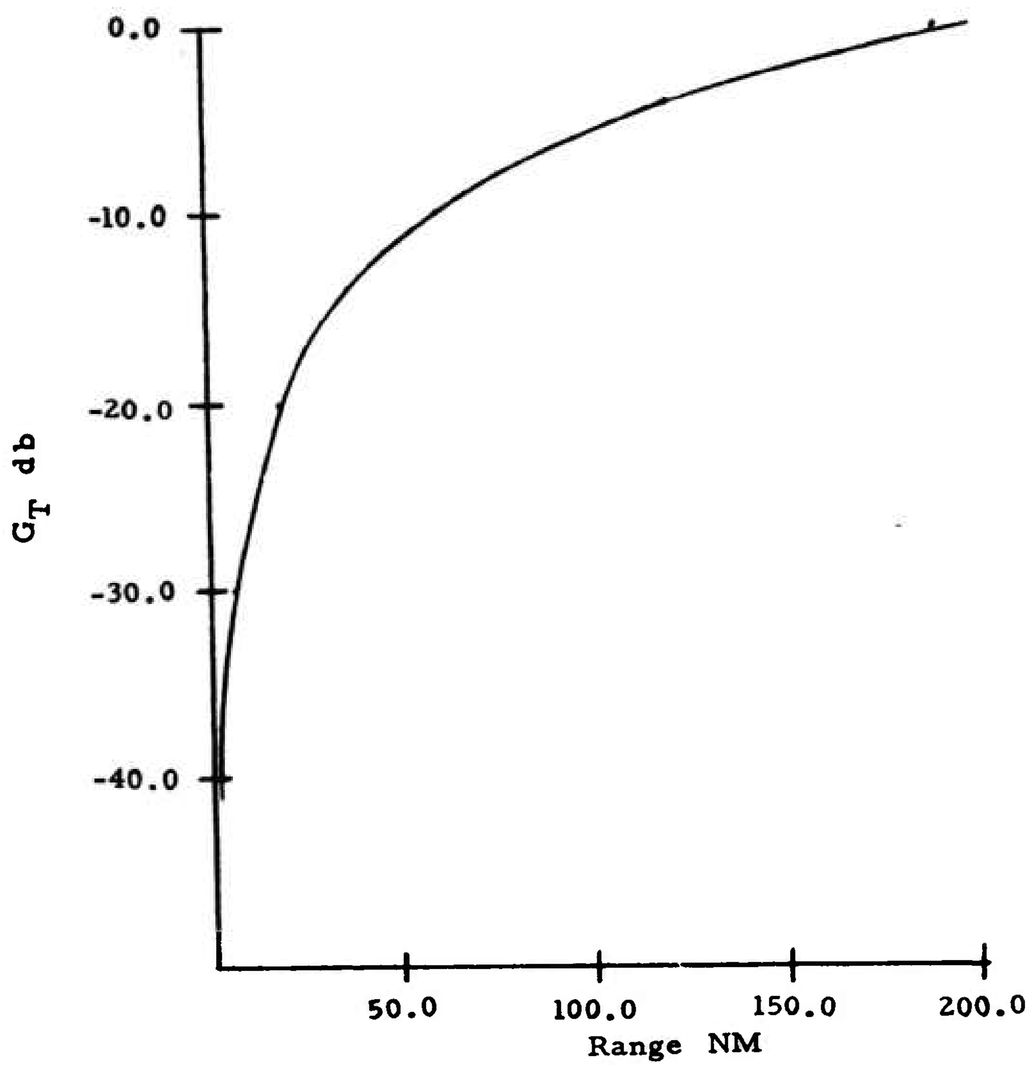


Figure 32 Antenna Attenuation Effects on Maximum Usable Range

deficiency reports (DR) on the test project. These reports should be prepared with care to present the data in a clear, concise manner.

The progress reports are required to keep the System Program Office (SPO) and management informed on the status of the test. This report should summarize the results of the tests for the reporting period, indicate any problems encountered, and briefly describe what tasks remain.

The final report should contain all the information known about the antenna system. The main body of the report should show how the test was accomplished; typical antenna pattern on each frequency, antenna, and aircraft configuration; and conclusions and recommendations on the ability of the radiating system to perform its designed function. The conclusions should specify the presence of any large null areas and the probable effect on the overall performance of the antenna system. Line losses and voltage standing wave ratio (VSWR) at each test frequency should also be presented.

The appendix to the report should contain all the data which lead to the conclusions in the report. This would include all the plotted antenna patterns which were determined to be valid.

In preparing the final report, the Systems Engineer should always consider the final user of the data. As such, the information presented should contain the data which may be required to effectively identify the characteristics of the radiating systems.

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APPENDIX A

PRECISION ANTENNA MEASUREMENT SYSTEM (PAMS)

The Precision Antenna Measurement System is a recently developed facility which represents the present state-of-the-art in dynamic measurement of airborne RF antenna radiating characteristics. This system is presently operated by the Technical Support Division of the Rome Air Development Center (RADC) at Griffiss AFB, New York. The PAMS facility is located at the Verona Annex of RADC at Verona, New York.

PAMS is an automated system which can measure up to 12 CW, AM, FM, or pulsed signals simultaneously and is capable of measuring signal strength, integrated power spectral density between pairs of frequencies, and radar cross sectional areas. Data may be recorded with horizontal or vertical linear polarizations or left or right circular polarizations simultaneously. This gives the system the capability of measuring up to 24 antenna patterns simultaneously. Through the use of a HP 2116B computer each frequency is automatically calibrated in one dbm steps producing high accuracy in the calibrated signal.

The PAMS concept is illustrated in figure A1. The system consists of: (1) an airborne monitoring recorder system, which records on seven track magnetic tape the aircraft heading, pitch, roll, and time for use during postflight data reduction, (2) six airborne signal sources used to provide stable 10 watt signals between .2 GHz and 18 GHz, (3) tracking receiving antennas, (4) FPS-16 tracking radar, (5) console to control the data sampling and monitor the received signals, and (6) computer system to reduce the recorded data.

Through the use of the Airborne Monitoring System (AMS) and the FPS-16 radar, the aircraft can fly any flight pattern. This enables the flight pattern to be designed to measure specific data requirements.

The PAMS facility is the best system presently available to perform antenna pattern testing above 1 GHz. If patterns are required on antennas above this frequency the PAMS range should be used.

To perform a test at PAMS the following organization should be contacted:

RADC/TUTV (M. E. Cook)
Griffiss AFB NY

Mr. Ed Cook is the PAMS engineer and can be contacted by autovon at 587-4227 to arrange testing on the PAMS range.

Additional information on PAMS can be found in the following two reports from RADC: (1) Precision Antenna Measurement System (PAMS), RADC-TR-73-233, August 1973, AD 915581L, (2) PAMS Airborne Instrumentation, RADC-TR-74-144, July 1974.

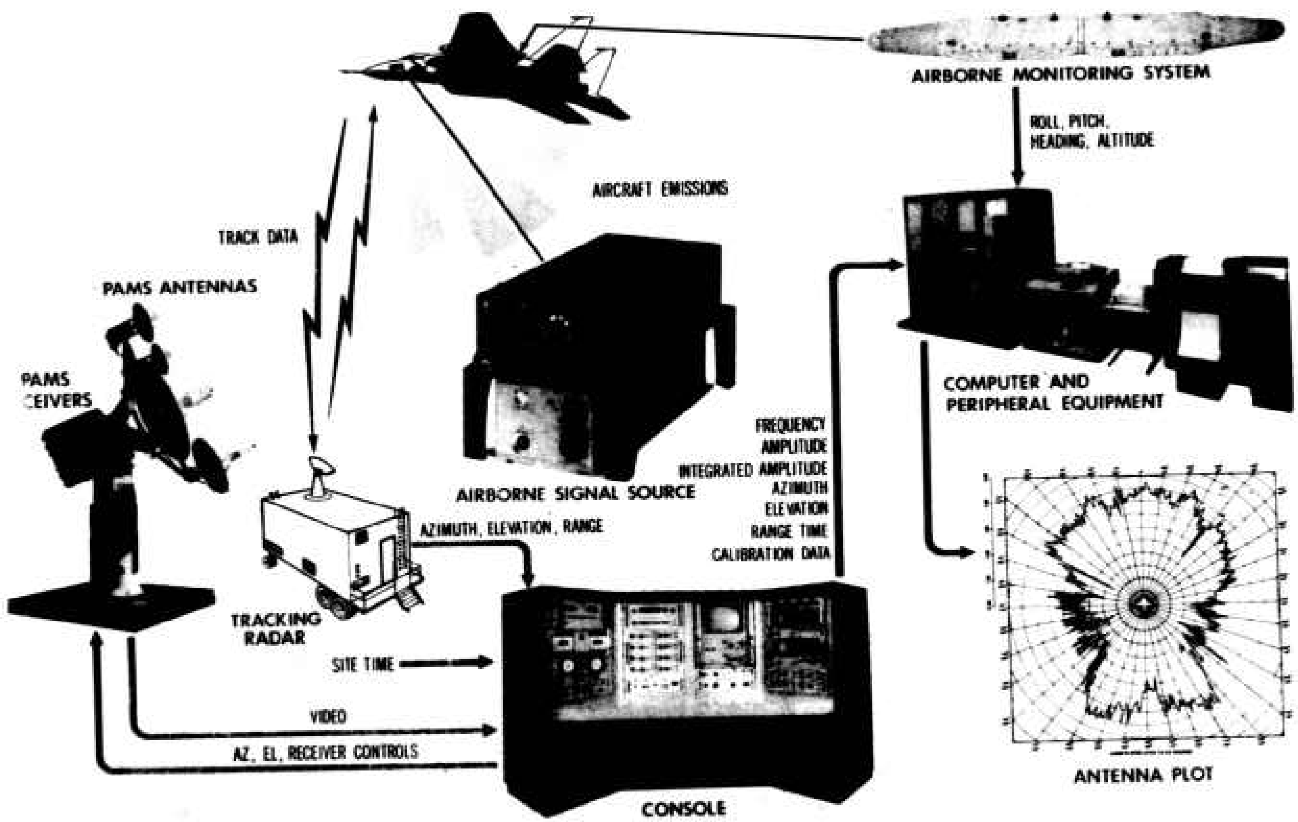

Figure A1 PAMS Concept

APPENDIX B

ANTENNA RADIATION PATTERN MEASUREMENT PROGRAM (ARPMP)
Deck Number 4701

INTRODUCTION

The Antenna Radiation Pattern Measurement Program (ARPMP) is a software package developed to provide the Systems Engineer with an automated system for measuring aircraft antenna radiation patterns. The program is used for postflight reduction of data recorded on magnetic tape during an antenna pattern measurement flight and calculates the effective radiated power (ERP) transmitted, aspect angle, depression angle, horizontal range of the aircraft to the receiving antenna, and time. The data read off the magnetic tapes are in 0.1 second intervals. For continuous patterns (orbits, radials, and parallel flybys) this data is averaged for 0.5 second and for discrete patterns (cloverleaf and polygon) the data is averaged for 2 seconds. The processed data is both printed and written to permanent storage for use by the Antenna Data Analysis Program (ADAP).

SYSTEM OVERVIEW

ARPMP consists of a main program and 14 subprograms which are each designed to perform specific tasks (calibration, read signal tape, read radar tape, etc.). The main program and executive subprogram READD are used to control the operation of the program.

The input/output requirements of the program are shown in figure B1. The signal tape is the digitized FM magnetic tape which contains the calibration signals and received signal strength of each signal source being recorded. The tape also contains the IRIG "B" time for use in correlating the data with radar and aircraft heading data.

The radar tape is the tape created by the Radar Computer Program of AFFTC/DOETDA. The tape contains the X, Y, Z location of the aircraft relative to the receiving antenna and IRIG "B" time. This tape contains other information on the aircraft's flight path but only the location is used by ARPMP.

The card input to the program defines all the parameters necessary for the processing of the tapes. This includes calibration data, flight times, flight pattern type, and options to use in reducing the data. The options available include: (1) processing radial flight data without radar tapes, (2) using both pre- and post-calibration points on the signal tape, and (3) correcting signal strength for multipath radiation. The input cards select one of three basic flight paths flown by the aircraft. The flight paths are: (1) radial or parallel flyby (constant heading legs), (2) cloverleafs or polygon (discrete points), and (3) orbits (continuous changing heading).

The output data from ARPMP consists of an output file and a computer listing (figure B2). The output file contains all the processed data and is stored on either magnetic tape or disc. The data file can be used by ADAP to produce polar plots or range versus signal plots. The output listing contains all the input cards read and a copy of all

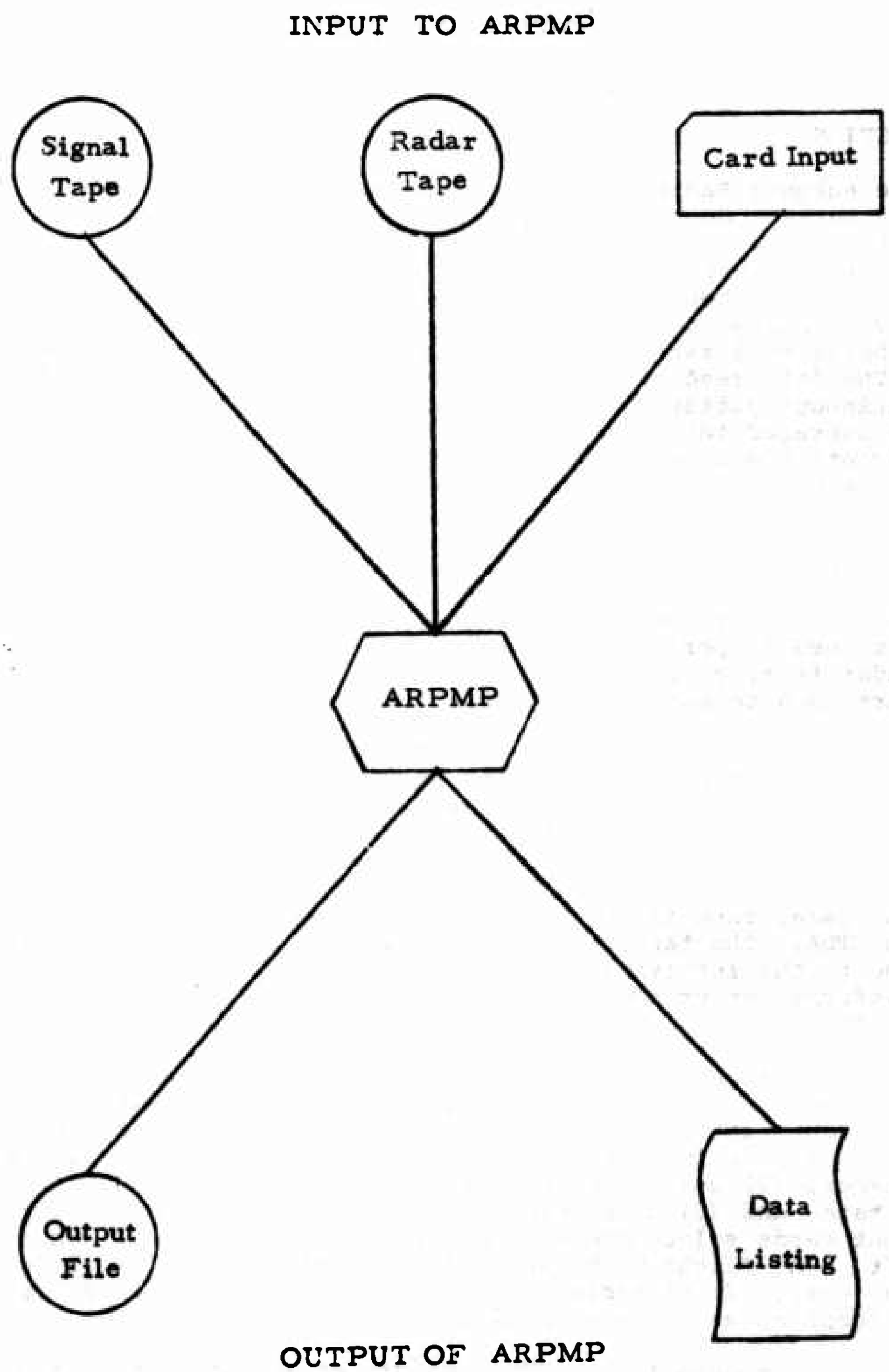

Figure B1 ARPMP Input/Output Requirements

```
                         AIRCRAFT ANTENNA RADIATION PATTERN PROGRAM
        4 DEC 1974    C-131  ORBIT FLIGHT    OPS 338-75       RUN NO. 1

THE NUMBER CF DIFFERENT FLIGHT PATTERNS ARE     5
NUMBER OF SOURCES ARE     2          RADAR = Y   NUMBER OF RANGES =    -0  AC ALT =       -0.00
 PRE AND POST  CALS  = Y START DAY =  339
MULTIPATH SIGNAL ELIMINATED = Y
SOURCE NUMBER     1FREQUENCY =  139.800MHZ   SYSTEM  LOSSES =  1.00 DB RECEIVER GAIN = -0.00 DB
SOURCE NUMBER     2FREQUENCY =  264.600MHZ   SYSTEM  LOSSES =  1.10 DB RECEIVER GAIN = -0.00 DB
SOURCE NUMBER  1 ANTENNA HEIGHT =   27.000 PERMITTIVITY =    9.300 CONDUCTIVITY =      .001
 THE CALCULATED REFLECTIVITY =      9.300     -.129 J
SOURCE NUMBER  2 ANTENNA HEIGHT =   29.000 PERMITTIVITY =    4.500 CONDUCTIVITY =      .001
 THE CALCULATED REFLECTIVITY =      4.500     -.068 J

TAG     SOURCE
  1          M03001 10/1  TO  THRU               REC 2   TRACK 3 IRIG 10  139.8 MHZ
  2          M03001 13/1  TO  THRU               REC 1   TRACK 3 IRIG 13 264.6 MHZ

THE NUMBER OF CALIBRATION SETS ARE    6

THE CALIBRATION SIGNAL IN DBM IS   -40.2000
THE CORRESPONDING TIME IS  2 HRS 17 MINS 25 SECS

THE CALIBRATION SIGNAL IN DBM IS   -50.2000
THE CORRESPONDING TIME IS  2 HRS 17 MINS 45 SECS

THE CALIBRATION SIGNAL IN DBM IS   -60.2000
THE CORRESPONDING TIME IS  2 HRS 18 MINS  0 SECS

THE CALIBRATION SIGNAL IN DBM IS   -70.2000
THE CORRESPONDING TIME IS  2 HRS 18 MINS 15 SECS

THE CALIBRATION SIGNAL IN DBM IS   -80.2000
THE CORRESPONDING TIME IS  2 HRS 18 MINS 35 SECS

THE CALIBRATION SIGNAL IN DBM IS   -90.2000
THE CORRESPONDING TIME IS  2 HRS 18 MINS 50 SECS

THE NUMBER OF CALIBRATION SETS ARE    6

THE CALIBRATION SIGNAL IN DBM IS   -60.5000
THE CORRESPONDING TIME IS  2 HRS  3 MINS 50 SECS

THE CALIBRATION SIGNAL IN DBM IS   -70.5000
THE CORRESPONDING TIME IS  2 HRS  4 MINS  5 SECS

THE CALIBRATION SIGNAL IN DBM IS   -80.5000
THE CORRESPONDING TIME IS  2 HRS  4 MINS 15 SECS

THE CALIBRATION SIGNAL IN DBM IS   -90.5000
THE CORRESPONDING TIME IS  2 HRS  4 MINS 30 SECS

THE CALIBRATION SIGNAL IN DBM IS  -100.5000
THE CORRESPONDING TIME IS  2 HRS  4 MINS 45 SECS

THE CALIBRATION SIGNAL IN DBM IS  -110.5000
THE CORRESPONDING TIME IS  2 HRS  4 MINS 56 SECS

 TIME Z   DBM    SIGNAL   TIME Z   DBM    SIGNAL   TIME Z   DBM    SIGNAL   TIME Z   DBM    SIGNAL   TIME Z   DBM    SIGNAL
 21725   -40.2   1645.0   21745   -50.2   1966.8   218 0   -60.2   2398.0   21815   -70.2   2852.5   21835   -80.2  ,3211.5
 21850   -90.2   3308.3   2 350   -60.5   1307.0   2 4 5   -70.5   1805.5   2 415   -80.5   2339.8   2 430   -90.5   2748.3
 2 445 -100.5    3058.5   2 456 -110.5    3071.0
```

Figure B2 ARPMP Output Listing

```
THE NUMBER OF CALIBRATION SETS ARE    6

THE CALIBRATION SIGNAL IN DBM IS    -40.2000
THE CORRESPONDING TIME IS 23 HRS 20 MINS  7 SECS

THE CALIBRATION SIGNAL IN DBM IS    -50.2000
THE CORRESPONDING TIME IS 23 HRS 20 MINS 20 SECS

THE CALIBRATION SIGNAL IN DBM IS    -60.2000
THE CORRESPONDING TIME IS 23 HRS 20 MINS 32 SECS

THE CALIBRATION SIGNAL IN DBM IS    -70.2000
THE CORRESPONDING TIME IS 23 HRS 20 MINS 45 SECS

THE CALIBRATION SIGNAL IN DBM IS    -80.2000
THE CORRESPONDING TIME IS 23 HRS 21 MINS  0 SECS

THE CALIBRATION SIGNAL IN DBM IS    -90.2000
THE CORRESPONDING TIME IS 23 HRS 21 MINS 18 SECS

THE NUMBER OF CALIBRATION SETS ARE    6

THE CALIBRATION SIGNAL IN DBM IS    -60.5000
THE CORRESPONDING TIME IS 23 HRS 27 MINS  0 SECS

THE CALIBRATION SIGNAL IN DBM IS    -70.5000
THE CORRESPONDING TIME IS 23 HRS 27 MINS 15 SECS

THE CALIBRATION SIGNAL IN DBM IS    -80.5000
THE CORRESPONDING TIME IS 23 HRS 27 MINS 30 SECS

THE CALIBRATION SIGNAL IN DBM IS    -90.5000
THE CORRESPONDING TIME IS 23 HRS 27 MINS 45 SECS

THE CALIBRATION SIGNAL IN DBM IS   -100.5000
THE CORRESPONDING TIME IS 23 HRS 28 MINS  0 SECS

THE CALIBRATION SIGNAL IN DBM IS   -110.5000
THE CORRESPONDING TIME IS 23 HRS 28 MINS 20 SECS

 TIME Z  DBM    SIGNAL  TIME Z  DBM    SIGNAL  TIME Z  DBM    SIGNAL  TIME Z  DBM    SIGNAL  TIME Z  DBM    SIGNAL
2320 7  -40.2  1601.5 232020  -50.2  1910.8 232032  -60.2  2310.0 232045  -70.2  2769.0 2321 0  -80.2  3163.3
232118  -90.2  3313.5 2327 0  -60.5  1250.3 232715  -70.5  1691.5 232730  -80.5  2208.5 232745  -90.5  2645.8
2328 0 -100.5  2972.8 232820 -110.5  3084.8

 SOURCE NUMBER  1
SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL
    -40.2   1623.3      -50.2   1938.8      -60.2   2354.0      -70.2   2810.8      -80.2   3187.4
    -90.2   3310.9

 SOURCE NUMBER  2
SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL  SIGNAL DBM  SIGNAL
    -60.5   1278.6      -70.5   1748.5      -80.5   2274.1      -90.5   2697.0     -100.5   3015.6
   -110.5   3077.9
```

Figure B2 (Continued)

```
THE HEADING TYPE IS  3
THE NUMBER OF HEADINGS ARE  22
THE ROLL ANGLE IS   30
THE PITCH    ANGLE IS -0
START TIME IS  01311 STOP TIME IS  01441

THE HEADING ANGLE IS   210
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 11 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   225
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 15 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   240
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 20 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   255
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 23 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   270
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 27 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   285
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 31 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   300
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 36 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   315
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 40 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   330
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 45 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   345
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 50 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   360
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 13 MINS 55 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    15
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS  1 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    30
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS  5 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    45
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 10 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    60
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 14 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    75
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 18 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS    90
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 21 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   105
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 25 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   120
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 29 SECS          TO          -0 HRS -0 MINS -0 SECS
```

Figure B2 (Continued)

```
THE HEADING ANGLE IS   135
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 32 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   150
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 36 SECS          TO          -0 HRS -0 MINS -0 SECS

THE HEADING ANGLE IS   165
THE CORRESPONDING   TIME INTERVAL IS  0 HRS 14 MINS 41 SECS          TO          -0 HRS -0 MINS -0 SECS
TIME    799.500 NOT FOUND NO DATA BETWEEN    799.210 AND    800.310
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Figure B2 (Continued)

THE DATA ARRAY TO BE USED BY ADAP IS ----

SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)	SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)
1.000	13.236	-2.877	1.326	32.060	791.000	2.000	4.686	-2.877	1.326	32.060	791.000
1.000	12.725	-3.827	359.700	32.032	791.500	2.000	4.724	-3.827	359.700	32.032	791.500
1.000	12.158	-4.779	358.069	32.002	792.000	2.000	5.173	-4.779	358.069	32.002	792.000
1.000	11.404	-5.725	356.433	31.968	792.500	2.000	6.715	-5.725	356.433	31.968	792.500
1.000	11.068	-6.666	354.791	31.938	793.000	2.000	7.867	-6.666	354.791	31.938	793.000
1.000	10.556	-7.605	353.142	31.906	793.500	2.000	7.801	-7.605	353.142	31.906	793.500
1.000	10.415	-8.540	351.484	31.873	794.000	2.000	7.107	-8.540	351.484	31.873	794.000
1.000	10.758	-9.471	349.819	31.845	794.500	2.000	6.510	-9.471	349.819	31.845	794.500
1.000	11.121	-10.405	348.143	31.812	795.000	2.000	5.892	-10.405	348.143	31.812	795.000
1.000	11.880	-11.154	346.789	31.784	795.500	2.000	5.143	-11.154	346.789	31.784	795.500
1.000	12.408	-11.902	345.436	31.755	796.000	2.000	5.173	-11.902	345.436	31.755	796.000
1.000	12.751	-12.647	344.064	31.726	796.500	2.000	5.235	-12.647	344.064	31.726	796.500
1.000	12.918	-13.377	342.695	31.698	797.000	2.000	5.569	-13.377	342.695	31.698	797.000
1.000	13.086	-14.106	341.308	31.671	797.500	2.000	5.771	-14.106	341.308	31.671	797.500
1.000	13.035	-14.827	339.918	31.642	798.000	2.000	5.249	-14.827	339.918	31.642	798.000
1.000	12.808	-15.547	338.514	31.616	798.500	2.000	4.386	-15.547	338.514	31.616	798.500
1.000	12.222	-16.270	337.118	31.589	799.000	2.000	3.120	-16.270	337.118	31.589	799.000
1.000	11.638	-17.669	334.266	31.537	800.000	2.000	2.801	-17.669	334.266	31.537	800.000
1.000	11.610	-18.801	331.875	31.514	800.500	2.000	3.061	-18.801	331.875	31.514	800.500
1.000	11.013	-19.910	329.460	31.491	801.000	2.000	4.386	-19.910	329.460	31.491	801.000
1.000	9.977	-21.007	327.011	31.468	801.500	2.000	5.083	-21.007	327.011	31.468	801.500
1.000	9.555	-22.055	324.527	31.445	802.000	2.000	5.267	-22.055	324.527	31.445	802.000
1.000	9.681	-23.063	321.998	31.425	802.500	2.000	5.072	-23.063	321.998	31.425	802.500
1.000	10.550	-24.043	319.442	31.403	803.000	2.000	4.343	-24.043	319.442	31.403	803.000
1.000	11.114	-24.762	317.494	31.384	803.500	2.000	4.699	-24.762	317.494	31.384	803.500
1.000	11.174	-25.461	315.518	31.363	804.000	2.000	5.169	-25.461	315.518	31.363	804.000
1.000	10.731	-26.138	313.525	31.345	804.500	2.000	5.678	-26.138	313.525	31.345	804.500
1.000	10.442	-26.792	311.503	31.328	805.000	2.000	6.206	-26.792	311.503	31.328	805.000
1.000	9.496	-27.420	309.454	31.313	805.500	2.000	6.030	-27.420	309.454	31.313	805.500
1.000	8.836	-28.016	307.386	31.298	806.000	2.000	5.912	-28.016	307.386	31.298	806.000
1.000	8.569	-28.583	305.304	31.283	806.500	2.000	5.527	-28.583	305.304	31.283	806.500
1.000	8.389	-29.133	303.205	31.268	807.000	2.000	5.008	-29.133	303.205	31.268	807.000
1.000	8.354	-29.659	301.085	31.253	807.500	2.000	5.233	-29.659	301.085	31.253	807.500
1.000	8.503	-30.146	298.927	31.240	808.000	2.000	5.174	-30.146	298.927	31.240	808.000
1.000	8.894	-30.598	296.751	31.228	808.500	2.000	5.076	-30.598	296.751	31.228	808.500
1.000	10.008	-31.016	294.559	31.217	809.000	2.000	5.073	-31.016	294.559	31.217	809.000
1.000	11.582	-31.389	292.346	31.208	809.500	2.000	4.726	-31.389	292.346	31.208	809.500
1.000	12.640	-31.730	290.114	31.202	810.000	2.000	5.257	-31.730	290.114	31.202	810.000
1.000	13.098	-32.049	287.872	31.194	810.500	2.000	6.472	-32.049	287.872	31.194	810.500
1.000	12.911	-32.337	285.616	31.186	811.000	2.000	6.736	-32.337	285.616	31.186	811.000
480.000	0.000										

Figure B2 (Continued)

THE DATA ARRAY TO BE USED BY ADAP IS ----

SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)	SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)
1.000	13.042	-32.541	283.791	31.183	811.500	2.000	6.091	-32.541	283.791	31.183	811.500
1.000	12.339	-32.716	281.954	31.176	812.000	2.000	5.860	-32.716	281.954	31.176	812.000
1.000	11.639	-32.865	280.104	31.178	812.500	2.000	4.795	-32.865	280.104	31.178	812.500
1.000	11.090	-32.989	278.249	31.172	813.000	2.000	4.470	-32.989	278.249	31.172	813.000
1.000	10.893	-33.091	276.402	31.174	813.500	2.000	4.109	-33.091	276.402	31.174	813.500
1.000	11.133	-33.168	274.539	31.169	814.000	2.000	3.728	-33.168	274.539	31.169	814.000
1.000	11.133	-33.217	272.687	31.169	814.500	2.000	4.146	-33.217	272.687	31.169	814.500
1.000	11.945	-33.238	270.829	31.175	815.000	2.000	4.681	-33.238	270.829	31.175	815.000
1.000	12.185	-33.234	268.962	31.174	815.500	2.000	5.004	-33.234	268.962	31.174	815.500
1.000	12.405	-33.206	267.100	31.176	816.000	2.000	5.632	-33.206	267.100	31.176	816.000
1.000	11.924	-33.136	264.794	31.181	816.500	2.000	5.957	-33.136	264.794	31.181	816.500
1.000	11.685	-33.028	262.489	31.187	817.000	2.000	5.350	-33.028	262.489	31.187	817.000
1.000	11.096	-32.883	260.200	31.194	817.500	2.000	4.608	-32.883	260.200	31.194	817.500
1.000	9.500	-32.698	257.911	31.201	818.000	2.000	4.058	-32.698	257.911	31.201	818.000
1.000	9.918	-32.479	255.627	31.210	818.500	2.000	4.329	-32.479	255.627	31.210	818.500
1.000	10.402	-32.223	253.374	31.218	819.000	2.000	4.788	-32.223	253.374	31.218	819.000
1.000	10.624	-31.928	251.125	31.227	819.500	2.000	5.057	-31.928	251.125	31.227	819.500
1.000	11.175	-31.601	248.888	31.241	820.000	2.000	5.783	-31.601	248.888	31.241	820.000
1.000	11.113	-31.310	247.100	31.257	820.500	2.000	5.826	-31.310	247.100	31.257	820.500
1.000	11.532	-30.996	245.322	31.267	821.000	2.000	5.581	-30.996	245.322	31.267	821.000
1.000	11.580	-30.662	243.558	31.280	821.500	2.000	5.813	-30.662	243.558	31.280	821.500
1.000	11.629	-30.306	241.805	31.299	822.000	2.000	5.457	-30.306	241.805	31.299	822.000
1.000	11.536	-29.938	240.059	31.312	822.500	2.000	5.176	-29.938	240.059	31.312	822.500
1.000	12.045	-29.544	238.333	31.332	823.000	2.000	5.162	-29.544	238.333	31.332	823.000
1.000	12.299	-29.121	236.624	31.348	823.500	2.000	5.357	-29.121	236.624	31.348	823.500
1.000	12.414	-28.682	234.937	31.367	824.000	2.000	4.886	-28.682	234.937	31.367	824.000
1.000	12.595	-28.225	233.254	31.388	824.500	2.000	4.188	-28.225	233.254	31.388	824.500
1.000	12.534	-27.750	231.582	31.408	825.000	2.000	4.555	-27.750	231.582	31.408	825.000
1.000	12.365	-27.260	229.927	31.429	825.500	2.000	5.531	-27.260	229.927	31.429	825.500
1.000	12.547	-26.754	228.288	31.453	826.000	2.000	6.223	-26.754	228.288	31.453	826.000
1.000	12.641	-26.233	226.668	31.477	826.500	2.000	6.819	-26.233	226.668	31.477	826.500
1.000	12.647	-25.691	225.065	31.500	827.000	2.000	6.557	-25.691	225.065	31.500	827.000
1.000	12.204	-25.127	223.475	31.524	827.500	2.000	6.088	-25.127	223.475	31.524	827.500
1.000	11.892	-24.558	221.899	31.547	828.000	2.000	5.714	-24.558	221.899	31.547	828.000
1.000	11.582	-23.975	220.333	31.573	828.500	2.000	4.961	-23.975	220.333	31.573	828.500
1.000	10.780	-23.381	218.785	31.600	829.000	2.000	4.664	-23.381	218.785	31.600	829.000
1.000	10.372	-22.772	217.253	31.629	829.500	2.000	4.196	-22.772	217.253	31.629	829.500
1.000	10.686	-22.155	215.740	31.656	830.000	2.000	4.299	-22.155	215.740	31.656	830.000
1.000	11.120	-21.517	214.239	31.685	830.500	2.000	4.440	-21.517	214.239	31.685	830.500
1.000	11.587	-20.868	212.744	31.714	831.000	2.000	4.680	-20.868	212.744	31.714	831.000
480.000	0.000										

TIME 838.500 NOT FOUND NO DATA BETWEEN 638.250 AND 839.350

Figure B2 (Continued)

THE DATA ARRAY TO BE USED BY ADAP IS ----

SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)	SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)
1.000	12.275	-20.216	211.263	31.746	831.500	2.000	4.441	-20.216	211.263	31.746	831.500
1.000	12.655	-19.556	209.796	31.776	832.000	2.000	4.430	-19.556	209.796	31.776	832.000
1.000	12.751	-18.891	208.345	31.805	832.500	2.000	4.514	-18.891	208.345	31.805	832.500
1.000	12.627	-18.215	206.905	31.834	833.000	2.000	4.294	-18.215	206.905	31.834	833.000
1.000	12.133	-17.533	205.480	31.867	833.500	2.000	3.998	-17.533	205.480	31.867	833.500
1.000	11.594	-16.834	204.063	31.899	834.000	2.000	3.627	-16.834	204.063	31.899	834.000
1.000	11.395	-16.131	202.653	31.933	834.500	2.000	3.471	-16.131	202.653	31.933	834.500
1.000	10.911	-15.428	201.254	31.964	835.000	2.000	2.852	-15.428	201.254	31.964	835.000
1.000	11.183	-14.836	200.090	31.997	835.500	2.000	3.330	-14.836	200.090	31.997	835.500
1.000	11.104	-14.237	198.933	32.031	836.000	2.000	4.253	-14.237	198.933	32.031	836.000
1.000	11.180	-13.636	197.789	32.067	836.500	2.000	4.605	-13.636	197.789	32.067	836.500
1.000	11.298	-13.032	196.651	32.101	837.000	2.000	5.324	-13.032	196.651	32.101	837.000
1.000	11.888	-12.418	195.517	32.137	837.500	2.000	5.943	-12.418	195.517	32.137	837.500
1.000	11.875	-11.805	194.395	32.171	838.000	2.000	6.237	-11.805	194.395	32.171	838.000
1.000	11.785	-10.577	192.166	32.242	839.000	2.000	6.608	-10.577	192.166	32.242	839.000
1.000	11.816	-9.959	191.055	32.276	839.500	2.000	6.351	-9.959	191.055	32.276	839.500
1.000	11.662	-9.336	189.947	32.313	840.000	2.000	6.646	-9.336	189.947	32.313	840.000
1.000	11.562	-8.707	188.854	32.350	840.500	2.000	6.686	-8.707	188.854	32.350	840.500
1.000	11.703	-8.085	187.758	32.384	841.000	2.000	6.676	-8.085	187.758	32.384	841.000
1.000	11.756	-7.155	186.122	32.421	841.500	2.000	6.952	-7.155	186.122	32.421	841.500
1.000	11.668	-6.218	184.497	32.458	842.000	2.000	6.291	-6.218	184.497	32.458	842.000
1.000	11.525	-5.283	182.872	32.495	842.500	2.000	6.491	-5.283	182.872	32.495	842.500
1.000	11.272	-4.350	181.251	32.530	843.000	2.000	6.539	-4.350	181.251	32.530	843.000
1.000	11.456	-3.416	179.632	32.566	843.500	2.000	6.053	-3.416	179.632	32.566	843.500
1.000	11.225	-2.484	178.018	32.602	844.000	2.000	6.044	-2.484	178.018	32.602	844.000
1.000	10.885	-1.549	176.406	32.639	844.500	2.000	5.559	-1.549	176.406	32.639	844.500
1.000	10.928	-.611	174.802	32.676	845.000	2.000	5.566	-.611	174.802	32.676	845.000
1.000	10.916	.131	173.517	32.711	845.500	2.000	5.385	.131	173.517	32.711	845.500
1.000	11.538	.866	172.229	32.748	846.000	2.000	5.147	.866	172.229	32.748	846.000
1.000	10.781	1.599	170.939	32.783	846.500	2.000	4.871	1.599	170.939	32.783	846.500
1.000	10.112	2.327	169.653	32.818	847.000	2.000	4.957	2.327	169.653	32.818	847.000
1.000	9.508	3.052	168.372	32.853	847.500	2.000	4.072	3.052	168.372	32.853	847.500
1.000	8.926	3.780	167.095	32.886	848.000	2.000	3.547	3.780	167.095	32.886	848.000
1.000	8.203	4.499	165.811	32.919	848.500	2.000	3.632	4.499	165.811	32.919	848.500
1.000	8.233	5.212	164.520	32.953	849.000	2.000	2.652	5.212	164.520	32.953	849.000
1.000	8.987	5.921	163.219	32.988	849.500	2.000	2.337	5.921	163.219	32.988	849.500
1.000	9.465	6.614	161.921	33.020	850.000	2.000	1.889	6.614	161.921	33.020	850.000
1.000	9.648	7.482	160.290	33.051	850.500	2.000	2.164	7.482	160.290	33.051	850.500
1.000	9.853	8.346	158.648	33.083	851.000	2.000	2.191	8.346	158.648	33.083	851.000
1.000	9.239	9.207	157.003	33.116	851.500	2.000	2.352	9.207	157.003	33.116	851.500
480.000	0.000										

Figure B2 (Continued)

THE DATA ARRAY TO BE USED BY ADAP IS ----

SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)	SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)
1.000	9.576	10.053	155.349	33.147	852.000	2.000	3.446	10.053	155.349	33.147	852.000
1.000	8.554	10.879	153.693	33.176	852.500	2.000	3.472	10.879	153.693	33.176	852.500
1.000	8.563	11.699	152.023	33.207	853.000	2.000	3.233	11.699	152.023	33.207	853.000
1.000	8.977	12.511	150.343	33.236	853.500	2.000	2.651	12.511	150.343	33.236	853.500
1.000	9.247	13.301	148.649	33.265	854.000	2.000	2.053	13.301	148.649	33.265	854.000
1.000	9.561	14.075	146.937	33.294	854.500	2.000	1.220	14.075	146.937	33.294	854.500
1.000	9.875	14.838	145.205	33.322	855.000	2.000	1.513	14.838	145.205	33.322	855.000
1.000	9.672	15.577	143.479	33.350	855.500	2.000	2.471	15.577	143.479	33.350	855.500
1.000	9.099	16.305	141.751	33.370	856.000	2.000	3.812	16.305	141.751	33.370	856.000
1.000	9.216	17.019	139.998	33.397	856.500	2.000	4.275	17.019	139.998	33.397	856.500
1.000	9.485	17.702	138.226	33.422	857.000	2.000	4.240	17.702	138.226	33.422	857.000
1.000	9.710	18.374	136.450	33.446	857.500	2.000	4.022	18.374	136.450	33.446	857.500
1.000	9.782	19.027	134.656	33.470	858.000	2.000	3.267	19.027	134.656	33.470	858.000
1.000	9.635	19.874	132.216	33.493	858.500	2.000	3.254	19.874	132.216	33.493	858.500
1.000	9.487	20.678	129.747	33.514	859.000	2.000	4.001	20.678	129.747	33.514	859.000
1.000	9.207	21.432	127.274	33.533	859.500	2.000	4.387	21.432	127.274	33.533	859.500
1.000	8.468	22.157	124.768	33.554	860.000	2.000	4.259	22.157	124.768	33.554	860.000
1.000	8.385	22.830	122.241	33.572	860.500	2.000	3.426	22.830	122.241	33.572	860.500
1.000	9.498	23.462	119.670	33.590	861.000	2.000	2.580	23.462	119.670	33.590	861.000
1.000	9.963	23.909	117.750	33.610	861.500	2.000	2.376	23.909	117.750	33.610	861.500
1.000	10.536	24.315	115.825	33.624	862.000	2.000	2.874	24.315	115.825	33.624	862.000
1.000	10.080	24.690	113.866	33.641	862.500	2.000	3.868	24.690	113.866	33.641	862.500
1.000	9.917	25.035	111.907	33.655	863.000	2.000	4.380	25.035	111.907	33.655	863.000
1.000	7.679	25.363	109.940	33.670	863.500	2.000	3.324	25.363	109.940	33.670	863.500
1.000	5.677	25.662	107.956	33.681	864.000	2.000	2.109	25.662	107.956	33.681	864.000
1.000	3.927	25.938	105.969	33.692	864.500	2.000	2.378	25.938	105.969	33.692	864.500
1.000	4.152	26.179	103.967	33.706	865.000	2.000	3.682	26.179	103.967	33.706	865.000
1.000	4.181	26.384	101.959	33.714	865.500	2.000	4.845	26.384	101.959	33.714	865.500
1.000	6.590	26.557	99.945	33.725	866.000	2.000	5.247	26.557	99.945	33.725	866.000
1.000	7.685	26.704	97.917	33.724	866.500	2.000	4.714	26.704	97.917	33.724	866.500
1.000	9.790	26.816	95.903	33.738	867.000	2.000	3.756	26.816	95.903	33.738	867.000
1.000	10.251	26.882	93.871	33.741	867.500	2.000	2.721	26.882	93.871	33.741	867.500
1.000	10.692	26.927	91.844	33.752	868.000	2.000	3.371	26.927	91.844	33.752	868.000
1.000	11.568	26.938	89.812	33.755	868.500	2.000	4.608	26.938	89.812	33.755	868.500
1.000	12.093	26.923	87.788	33.754	869.000	2.000	4.284	26.923	87.788	33.754	869.000
1.000	11.262	26.849	85.065	33.757	869.500	2.000	4.437	26.849	85.065	33.757	869.500
1.000	10.824	26.713	82.334	33.758	870.000	2.000	4.723	26.713	82.334	33.758	870.000
1.000	11.546	26.527	79.628	33.756	870.500	2.000	4.760	26.527	79.628	33.756	870.500
1.000	11.153	26.279	76.921	33.757	871.000	2.000	3.828	26.279	76.921	33.757	871.000
1.000	11.305	25.978	74.231	33.753	871.500	2.000	3.276	25.978	74.231	33.753	871.500
480.000	0.000										

Figure B2 (Continued)

THE DATA ARRAY TO BE USED BY ADAP IS ---

SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)	SOURCE	SIGNAL (DBW)	DEP ANGLE (DEG)	ASP ANGLE (DEG)	RANGE (NM)	TIME (TOTAL SEC)
1.000	11.435	25.629	71.555	33.749	872.000	2.000	2.503	25.629	71.555	33.749	872.000
1.000	11.515	25.334	69.591	33.751	872.500	2.000	1.914	25.334	69.591	33.751	872.500
1.000	12.608	24.998	67.612	33.744	873.000	2.000	2.312	24.998	67.612	33.744	873.000
1.000	11.555	24.638	65.654	33.736	873.500	2.000	3.299	24.638	65.654	33.736	873.500
1.000	11.495	24.251	63.737	33.726	874.000	2.000	4.038	24.251	63.737	33.726	874.000
1.000	11.623	23.831	61.787	33.715	874.500	2.000	4.150	23.831	61.787	33.715	874.500
1.000	10.[illegible]2	23.383	59.870	33.707	875.000	2.000	4.748	23.383	59.870	33.707	875.000
1.000	9.994	22.919	57.962	33.698	875.500	2.000	4.906	22.919	57.962	33.698	875.500
1.000	9.098	22.433	56.084	33.687	876.000	2.000	5.398	22.433	56.084	33.687	876.000
1.000	7.694	22.022	54.590	33.675	876.500	2.000	5.756	22.022	54.590	33.675	876.500
1.000	7.867	21.597	53.108	33.665	877.000	2.000	6.344	21.597	53.108	33.665	877.000
1.000	7.491	21.149	51.629	33.653	877.500	2.000	6.455	21.149	51.629	33.653	877.500
1.000	6.961	20.690	50.164	33.634	878.000	2.000	5.870	20.690	50.164	33.634	878.000
1.000	7.133	20.221	48.713	33.622	878.500	2.000	4.973	20.221	48.713	33.622	878.500
1.000	6.887	19.735	47.261	33.603	879.000	2.000	4.264	19.735	47.261	33.603	879.000
1.000	7.365	19.236	45.821	33.589	879.500	2.000	4.451	19.236	45.821	33.589	879.500
1.000	6.593	18.724	44.388	33.566	880.000	2.000	5.263	18.724	44.388	33.566	880.000
1.000	5.598	18.201	42.971	33.550	880.500	2.000	5.734	18.201	42.971	33.550	880.500
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
216.000	1.000										

SOURCE NUMBER	MIN SIGNAL	MAX SIGNAL	SOURCE NUMBER	MIN SIGNAL	MAX SIGNAL	SOURCE NUMBER	MIN SIGNAL	MAX SIGNAL
1	3.927	13.236	2	1.220	7.867			

Figure B2 (Continued)

the processed data. This can be used to check the validity of the data prior to plotting.

PREPARATION FOR USE

The program deck of ARPMP will be permanently stored on magnetic tape number 5540 in the tape library of building 3940. This tape contains four files which are: (1) ADAP LGO (compiled file), (2) ARPMP LGO (compiled file), (3) ADAP source file, and (4) ARPMP source file. Prior to the first use of these programs, the compiled file must be copied to disc and stored as a permanent file as shown in figure B3. Once the program is stored as a permanent file, it may be attached and executed.

USERS GUIDE

The execution of ARPMP requires a signal tape (TAPE10), radar tape (TAPE11), output tape (TAPE12), and a data deck. The mass storage files may be either magnetic tape files or disc files. For efficiency of operation, it is suggested these files be located on disc. This will reduce the execution time and free the program from requiring magnetic tape drives.

The input magnetic tape files may be copied to disc with a COPYBF macro and the MERGE option of ADAP. If more than one radar tapes are merged, the file should be created with increasing times. An example merge deck is shown in appendix C.

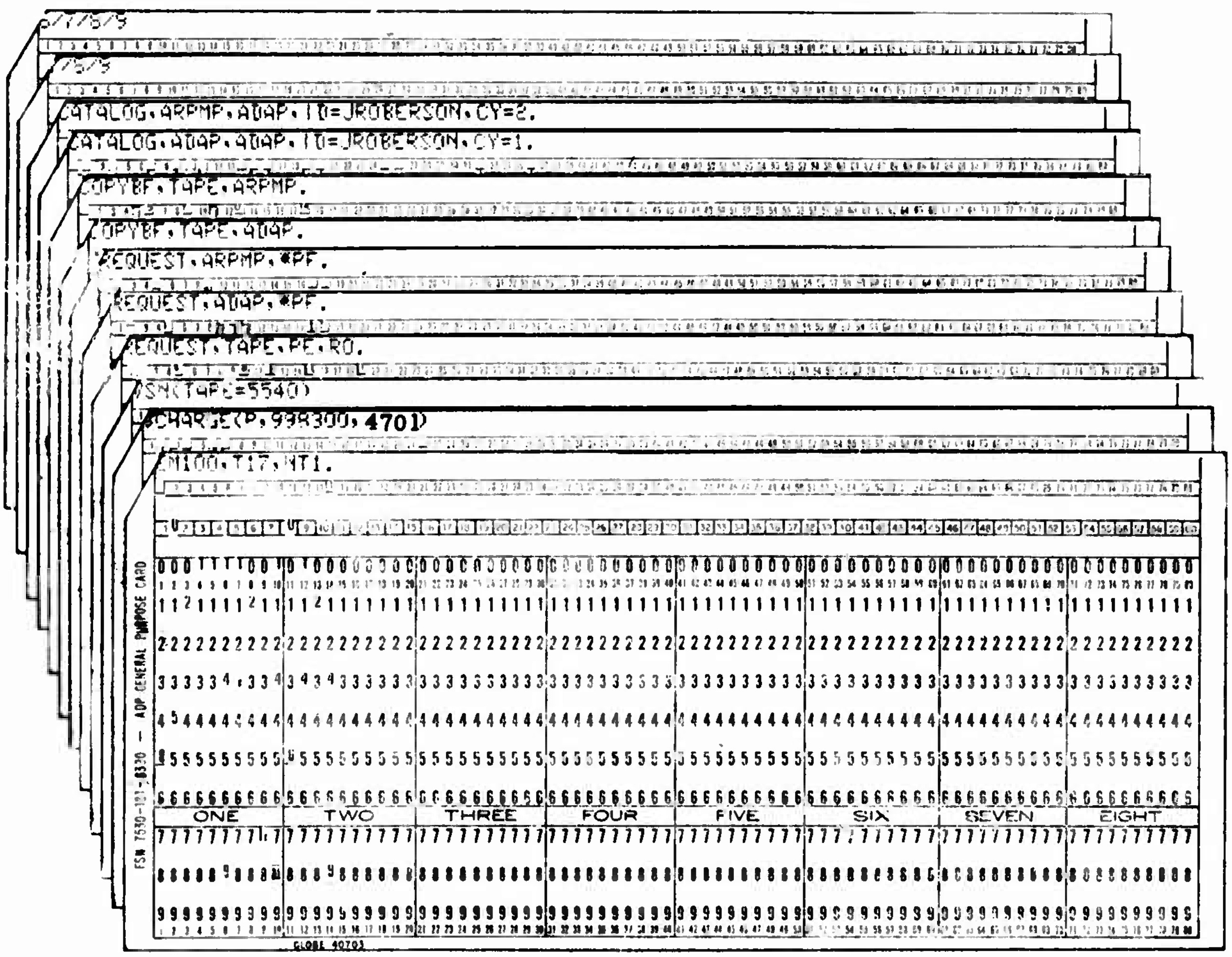
The deck developed for running ARPMP is composed of two parts. The first part is the job control cards to attach, request, catalog, and execute the program. Examples of these cards are shown in figures B13 and B14.

The second portion of this deck is the parameter identification cards which supply all the required card input data for the program. There are nine different types of data cards used by ARPMP. The selection and coding of the cards are described in the following section and shown in figures B4 through B12. Figures B13 and B14 are example data decks used for ARPMP.

<u>Input Cards for ARPMP</u>:

ARPMP card 1 (figure B4) is used to provide a descriptive heading on the ARPMP listing. Any comment may be written in the 80 column field to describe the data being processed. Normally items like date, OPS number, aircraft, and flight type will be recorded.

ARPMP card 2 (figure B5) is used to identify the options to be used and to identify the run. By coding a Y for YES or an N for NO in the appropriate columns, radar tape, pre- and post-calibration, or multipath correction options can be selected. The radar tape option N is only selected for radial flights without radar tracking. This will cause the program to calculate range based on time and range data supplied by ARPMP card 5. If two sets of calibration points are to be averaged to calibrate the signal tape, a Y is coded in column 2. If only one set is to be used an N is coded. Corrections of the signal strength for multipath radiation can be selected by coding a Y in column 3. If this option is selected the multipath effect is calculated by the



Note: **Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer**

Figure B3   Deck Setup to Copy ARPMP and ADAP to Permanent File

technique described in appendix E. Selecting this option will require ARPMP card 4 to be coded.

The number of flight patterns to be processed is coded in columns 4-10. For each flight pattern processed ARPMP cards 8-9 must be coded. The number of different signals recorded is recorded in columns 4-10. The Julian date (0-365) of the flight is coded in columns 21-30 and if a radar tape is not used the number of range entries is coded in columns 31-40 and the altitude of the flight (AGL) is coded in columns 41-50.

ARPMP card 3 (figure B6) is coded to identify each signal source recorded on the signal tape. The data recorded on this card are the frequency of the signal in MHz, line losses of the receiving system in db, and the gain of the receiving antenna in db. Data on two sources are recorded on each card with a maximum of 20 sources permitted. The order of recording the sources is the same as the order of the CAL records on the signal tape. This will normally be in the order of IRIG channels used to record the data on FM tape.

ARPMP card 4 (figure B7) is used only if the multipath correction option is selected. For each signal the receiving antenna height in feet, relative permittivity, and conductivity are entered in the same order as in ARPMP card 3. The conductivity and antenna height can either be measured or picked such that program MULT of ADAP predicts the location of each lobe to coincide with the measured lobes. The relative permittivity which best eliminates the multipath effect can be found by program MATCH of ADAP.

ARPMP card 5 (figure B8) is only used if the No Radar Tape option is selected. This card records the range at the end of the radial in NM and the time the aircraft was over the receiving antenna and at the end of the radial. To determine the range of the aircraft, time will be used for linear extrapolation of range between the start and end of the radial.

ARPMP card 6 (figure B9) will record the number of calibration points to be read on ARPMP card 7 (figure B10). Cards 6 and 7 will be coded for each set of calibration points recorded. The calibration points should be recorded in sequence, starting with the signal identified as source 1. If pre- and post-calibration points are used, the set of calibration points with the lowest times should be coded first. A maximum of 50 calibration points per source is permitted, with a maximum of 200 total points. Normally 10 calibration points per source will be sufficient.

ARPMP card 8 (figure B11) is used to provide data on the flight type. The first entry on this card identifies the basic flight technique. If the flight has legs of constant heading (radial or parallel flyby), a 1 is coded. If the pattern flown consists of discrete points (cloverleaf or polygon), a 2 will be coded. For flight pattern with constant turn rates and continuous data sampling, a 3 is coded.

In columns 11-20, the number of headings recorded on ARPMP card 9 is recorded. A maximum of 90 is permitted per pattern flown. The aircraft's attitude (roll and pitch) is recorded in columns 21-40. Right roll is recorded as positive and left roll as negative as measured in degrees from the horizontal. Pitch up is recorded as positive and pitch down as negative.

Parameter Ide .fication Card

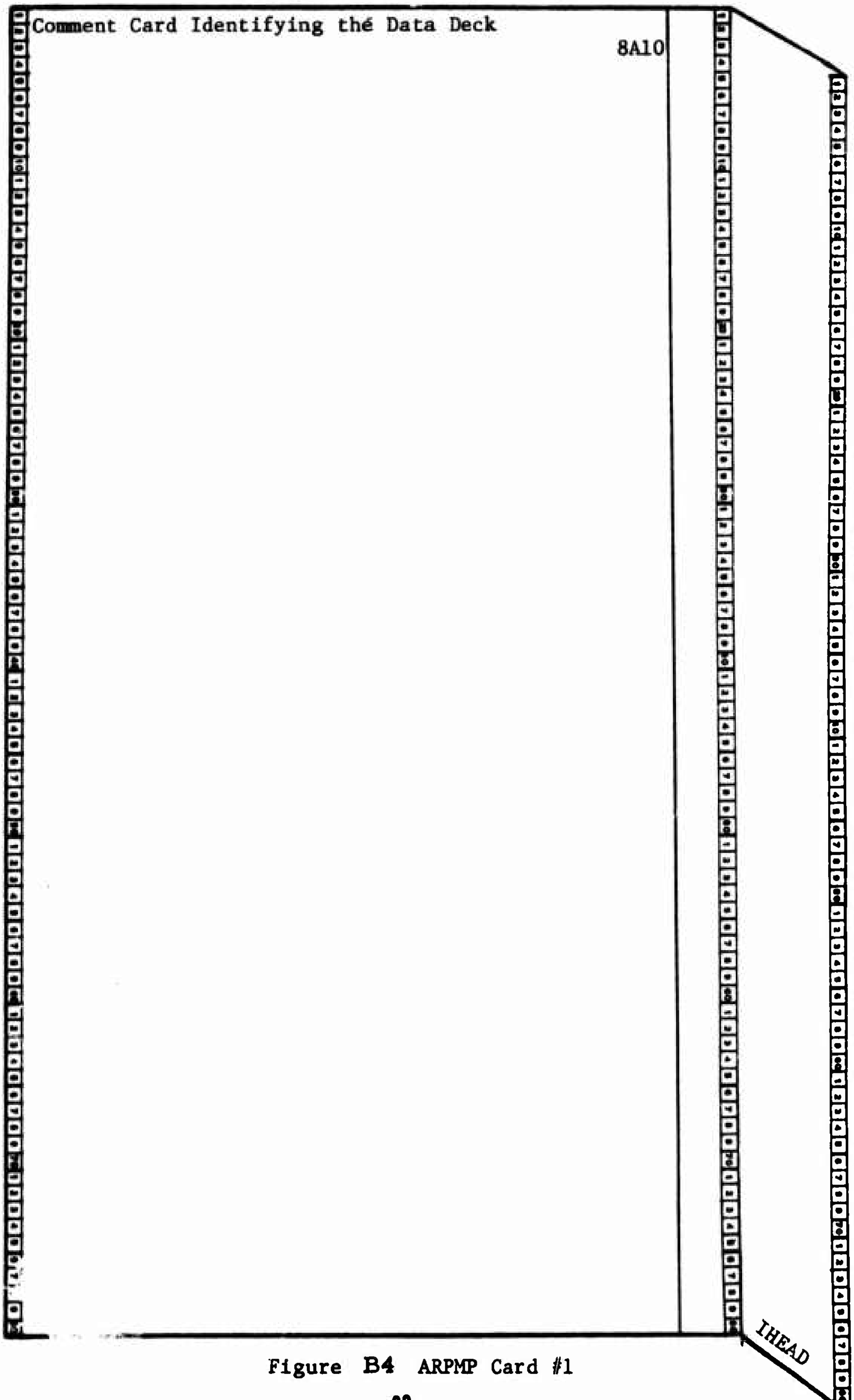


Figure B4 ARPMP Card #1

Parameter Identification Card

Field	Format	Variable
Is there a Radar Tape; Enter Y for Yes, N for No	A1	IRADAR
Are there Pre & Post Cals; Enter Y for Yes, N for No	A1	IPCAL
Is Multipath Option Used; Enter Y for Yes, N for No	A1	IMULT
Number of Different Flight Patterns	I7	NTYPP
Number of Different Signals Recorded (No. of Sources)	I10	NUMSR
Starting Day of the Flight (Julian)	I10	ISTDAT
Number of Ranges (Used only if no Radar Tape; otherwise left blank)	I10	NUMRNG
Altitude of Aircraft (Only if no Radar Tape; otherwise left blank) (AGL)	F10.3	ALTAC
Left Blank		

Figure B5 ARPMP Card #2

Parameter Identification Card

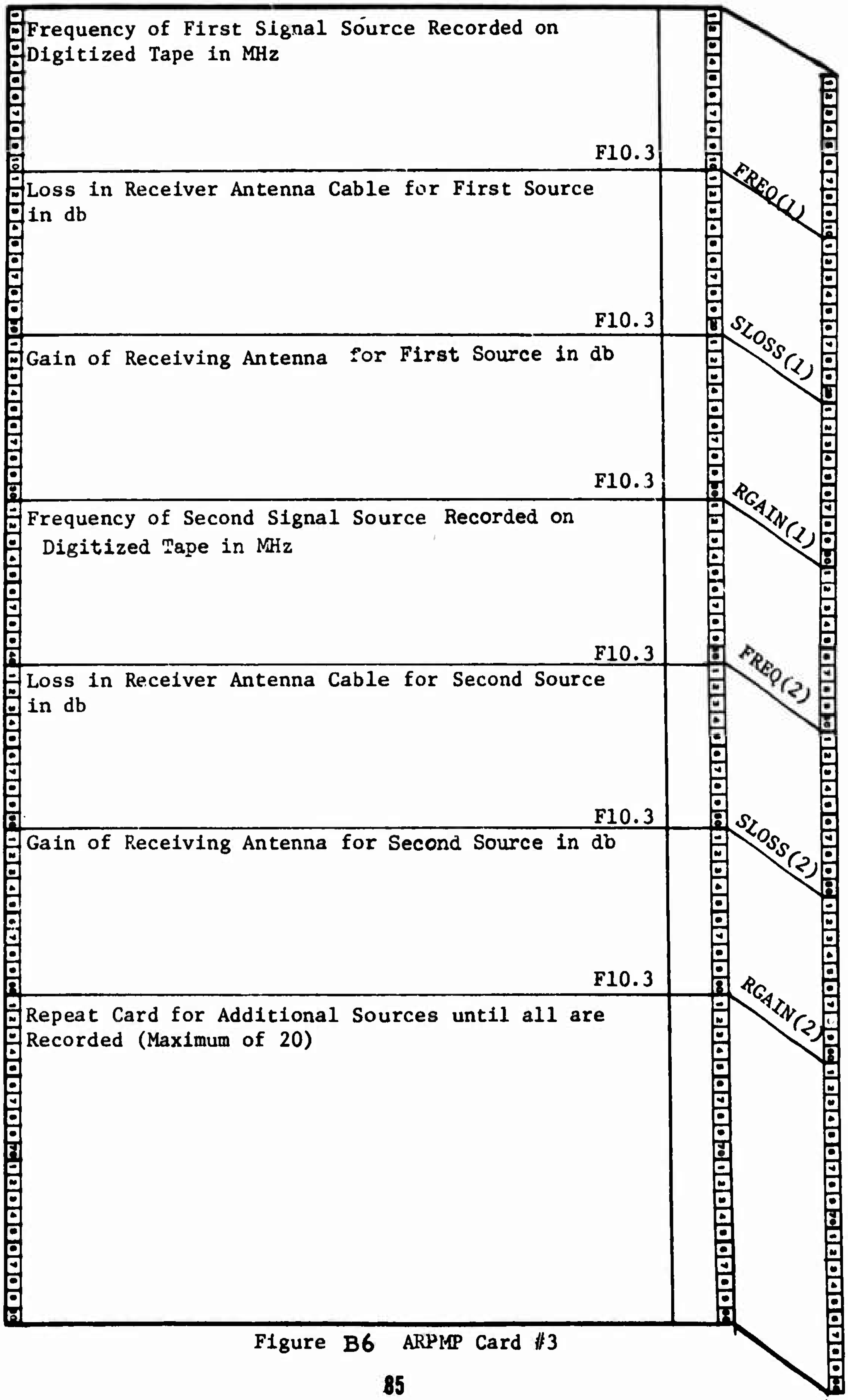


Figure B6 ARPMP Card #3

Parameter Identification Card

Field	Format	Variable
Height of Source #1 above Antenna Reflecting Surface (ft)	F10.3	ANTHT(1)
Relative Permittivity of Reflecting Surface	F10.3	PERM(1)
Conductivity of Reflecting Surface mho-meter/sq meter	F10.3	COND(1)
Antenna Height of Source #2 above Reflecting Surface (ft)	F10.3	ANTHT(2)
Relative Permittivity of Reflecting Surface	F10.3	PERM(2)
Conductivity of Reflecting Surface	F10.3	COND(2)
Repeat Card for Additional Sources until data is Recorded for all Sources (Maximum of 20)		

Figure B7 ARPMP Card #4

Parameter Identification Card

Field	Unit	Format	Variable
Distance from Receiver Site at End of Radial (NM)		F3.0	RDRNG (1,1)
Time Over Site	hours	I2	IHST(1)
	minutes	I2	IMST(1)
	seconds	I2	ISST(1)
Time at End of Radial	hours	I2	IHSP(1)
	minutes	I2	IMSP(1)
	seconds	I2	ISSP(1)
Distance from Receiver Site at End of Radial (NM)		F3.0	RDRNG (1,2)
Time Over Site	hours	I2	IHST(2)
	minutes	I2	IMST(2)
	seconds	I2	ISST(2)
Time at End of Radial	hours	I2	IHSP(2)
	minutes	I2	IMSP(2)
	seconds	I2	ISSP(2)
Distance from Receiver at End of Radial (NM)		F3.0	RDNG (1,3)
Time Over Site	hours	I2	IHST(3)
	minutes	I2	IMST(3)
	seconds	I2	ISST(3)
Time at End of Radial	hours	I2	IHSP(3)
	minutes	I2	IMSP(3)
	seconds	I2	ISSP(3)
Distance from Receiver at End of Radial		F3.0	RDNG(1,4)
Time Over Site	hours	I2	IHST(4)
	minutes	I2	IMST(4)
	seconds	I2	ISST(4)
Time at End of Radial	hours	I2	IHSP(4)
	minutes	I2	IMSP(4)
	seconds	I2	ISSP(4)

Figure B8 ARPMP Card #5

Parameter Identification Card

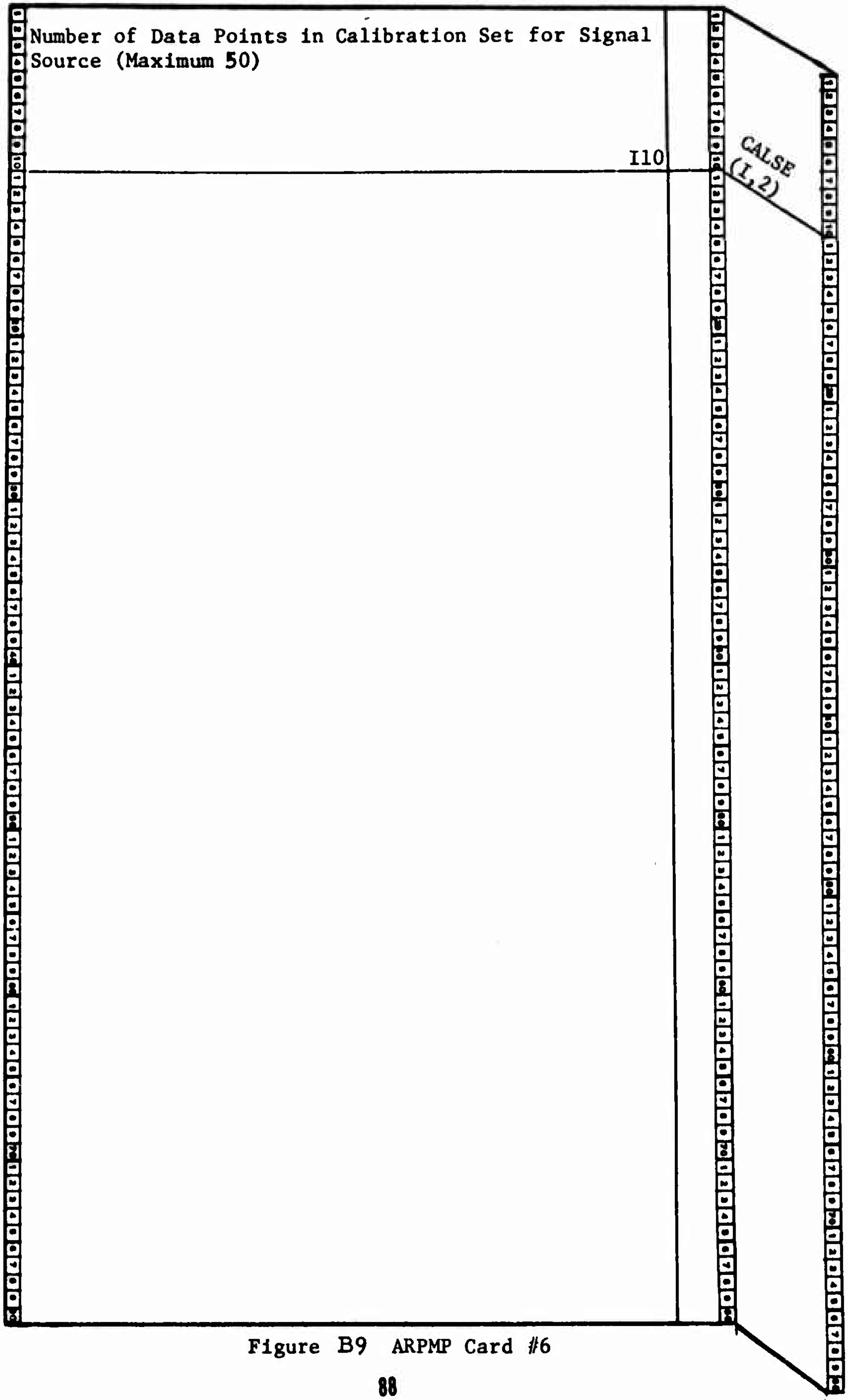


Figure B9 ARPMP Card #6

Parameter Identification Card

Field		Format	Variable
Calibrated Signal in dbm for Signal Source		F10.3	CALMV(1)
Time of Calibration	hours	I2	IHR(1)
	minutes	I2	IMIN(1)
	seconds	I2	ISEC(1)
Second Calibration Signal		F10.3	CALMV(2)
Time of Second Calibration	hours	I2	IHR(2)
	minutes	I2	IMIN(2)
	seconds	I2	ISEC(2)
Third Calibration Signal		F10.3	CALMV(3)
Time of Third Calibration	hours	I2	IHR(3)
	minutes	I2	IMIN(3)
	seconds	I2	ISEC(3)
Fourth Calibration Signal		F10.3	CALMV(4)
Time of Fourth Calibration	hours	I2	IHR(4)
	minutes	I2	IMIN(4)
	seconds	I2	ISEC(4)

Figure B10 ARPMP Card #7

Parameter Identification Card

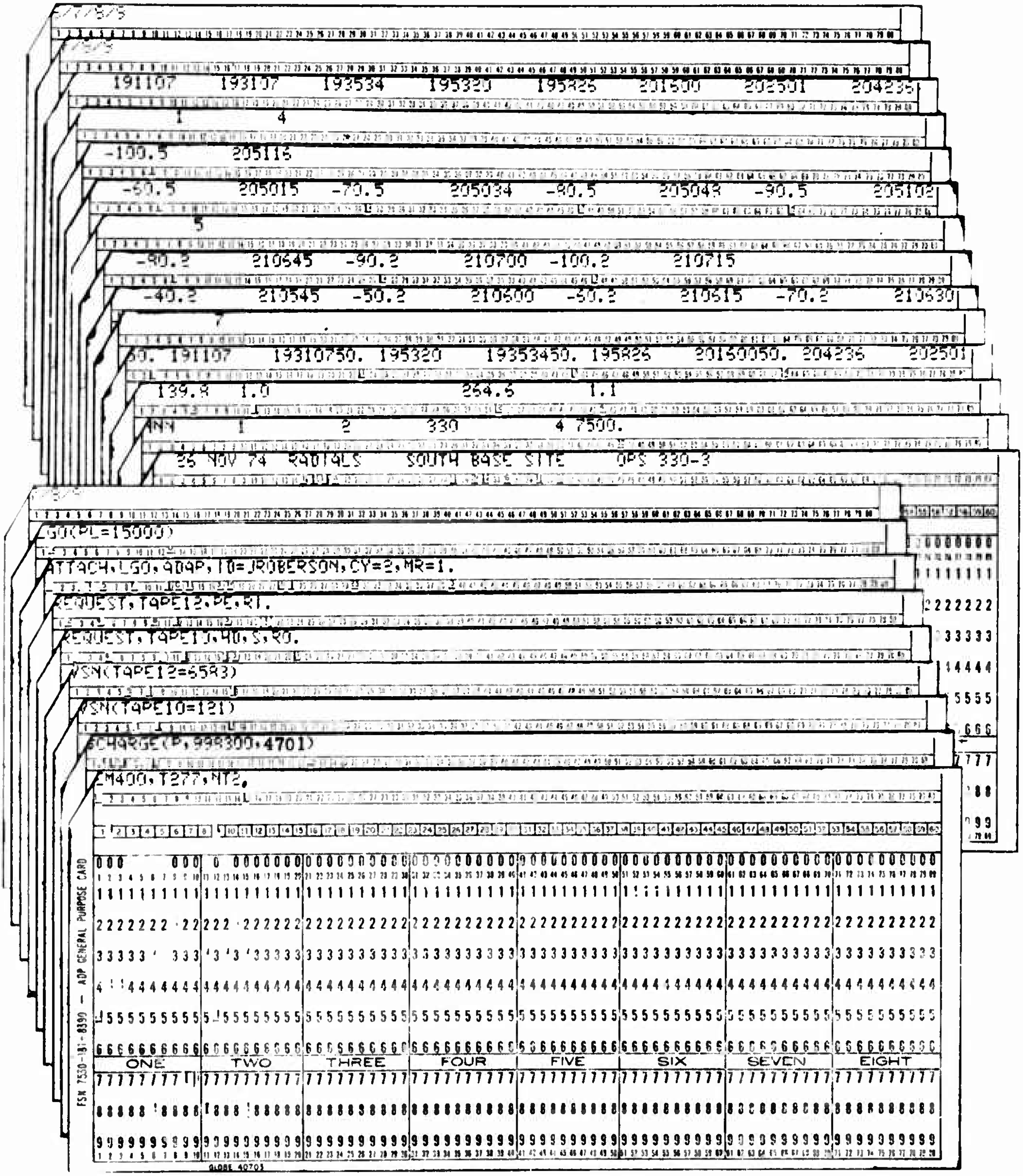
Field	Format	Variable
Type of Pattern Flown Code 1 for flyby, radial, or any pattern in which the heading is held constant during a time interval. Code 2 cloverleaf; polygon; or where data is sampled at discrete points. Code 3 orbits or flight which requires continuous data with continuous heading changes.	I10	IHDTYP
Number of Headings to be Entered (Maximum of 90)	I10	NUMHD
Roll Angle of Aircraft (Right roll is positive and left roll is negative)	I10	IROLL
Pitch Angle of Aircraft (Pitch up is positive and pitch down is negative)	I10	IPTCH
Start Time of data to be processed (not used for Type 2) — Hours	I2	IHST
Start Time of data to be processed (not used for Type 2) — Minutes	I2	IMST
Start Time of data to be processed (not used for Type 2) — Seconds	I2	ISST
Stop Time of data to be processed (not used for Type 2) — Hours	I2	IHSP
Stop Time of data to be processed (not used for Type 2) — Minutes	I2	IMSP
Stop Time of data to be processed (not used for Type 2) — Seconds	I2	ISSP

Figure B11 ARPMP Card # 8

Parameter Identification Card

Magnetic Heading for First Time		I3	IHED(1)
Start Time for First Heading	hours	I2	IHR1(1)
	minutes	I2	MIN1(1)
	seconds	I2	ISEC1(1)
Stop Time for First Heading	hours	I2	IHR2(1)
	minutes	I2	MIN2(1)
	seconds	I2	ISEC2(1)
Second Magnetic Heading		I3	IHED(2)
Start Time for Second Heading	hours	I2	IHR1(2)
	minutes	I2	MIN1(2)
	seconds	I2	ISEC1(2)
Stop Time for Second Heading	hours	I2	IHR2(2)
	minutes	I2	MIN2(2)
	seconds	I2	ISEC2(2)
Third Heading		I3	IHED(3)
Start Time	hours	I2	IHR1(3)
	minutes	I2	MIN1(3)
	seconds	I2	ISEC1(3)
Stop Time	hours	I2	IHR2(3)
	minutes	I2	MIN2(3)
	seconds	I2	ISEC2(3)
Fourth Heading		I3	IHED(4)
Start Time	hours	I2	IHR1(4)
	minutes	I2	MIN1(4)
	seconds	I2	ISEC1(4)
Stop Time	hours	I2	IHR2(4)
	minutes	I2	MIN2(4)
	seconds	I2	ISEC2(4)

Figure B12 ARPMP Card # 9



Note: **Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer**

Figure B13 Example ARPMP Deck

```
EM500.T277.
$CHARGE(P.998300.4701)
ATTACH.TAPE11.DATA.ID=JROBERSON.CY=1.MR=1.
ATTACH.TAPE10.DATA.ID=JROBERSON.CY=2.MR=1.
REQUEST.TAPE12.*PF.
ATTACH.LGO.ADAP.ID=JROBERSON.CY=2.MR=1.
LGO.
CATALOG.TAPE12.DATA.ID=JROBERSON.CY=3.MR=1.
7/8/9
           4 DEC 1974    C-131   ORBIT FLIGHT     OPS 338-75        RUN NO. 1
YYY        3          2          339
  139.8       1.0                 264.6      1.1
 27.       9.3       .001          29.       4.5        .001
           6
  -40.2        021725    -50.2       021745    -60.2       021800     -70.2      021815
   -80.2       021835    -90.2       021850
           5
  -60.5        020350    -70.5       020405    -80.5       020415     -90.5      020430
  -100.5       020445    -110.5      020456
           6
   -40.2       232007    -50.2       232020    -60.2       232032     -70.2      232045
  -80.2        232100    -90.2       232118
           6
  -60.5        232700    -70.5       232715   -80.5        232730     -90.5      232745
  -100.5       232800    -110.5      232820
           3          22          30                001311      001441
210 001311         225 001315          240 001320          255 001323
270 001327         285 001331          300 001336          315 001340
330 001345         345 001350          360 001355          015 001401
030 001405         045 001410          060 001414          075 001418
090 001421         105 001425          120 001429          135 001432
150 001436         165 001441
           3         25           15                001921      002313
030 001921         045 001931          060 001941          075 001950
090 002000         105 002009          120 002019          135 002028
150 002039         165 002048          180 002058          195 002107
210 002119         225 002127          240 002137          255 002145
270 002154         285 002205          300 002213          315 002223
330 002233         345 002243          360 002254          015 002303
030 002313
           2         73
350 004418         355 004427          360 004438          005 004450
010 004559         015 004507          020 004516          025 004528
030 004543         035 004551          040 004603          045 004612
050 004628         055 004639          060 004647          065 004658
070 004709         075 005154          080 005202          085 005209
091 005219         095 005227          100 005238          105 005246
110 005255         115 005305          121 005315          125 005325
130 005331         135 005341          140 005348          145 005358
150 005405         155 005415          161 005424          166 005433
170 005442         175 005450          180 005501          185 005509
191 005519         195 005525          200 005534          205 005544
211 005553         216 005603          220 005611          225 005620
230 005627         236 005636          240 005644          245 005653
250 005700         255 005709          260 005716          265 005725
270 005736         275 005744          279 005753          285 005804
291 005812         295 005820          300 005829          305 005835
311 005846         315 005855          320 005903          325 005913
330 005921         336 005930          341 005938          346 005949
349 005959
7/8/9
6/7/8/9
```

Note: Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer

Figure B14 Example ARPMP Deck

Columns 41-60 are used to record the start and stop times to be used for processing of flight's data for flight type 3. For flight types 1 and 2, the start and stop time entries are not required since the times are used for each heading entry on ARPMP card 9.

The last card is ARPMP card 9 (figure B12). This card contains all the headings and heading time intervals to be used in data processing. The headings recorded are magnetic headings as read off the aircraft's directional gyro. The headings, start time, and stop time are recorded four to a card with a maximum of 90 entries. For flight types 2 and 3 the stop times are left blank and if radar tapes are not used the heading may be left blank.

Program Description:

ARPMP was developed in a modular design to facilitate future program modifications. As such, the program uses 14 subprograms of which READD, CAL, SIGNAL, RADAR, MULTPTH are the main subroutines. The main program is responsible for initialization of data, reading control data cards, and initiating the data processing.

Subroutine CAL creates the arrays required by VCAL to calibrate the data on the signal tape in dbm. This subroutine reads data cards which give the time and signal recorded on the signal tape. Data are read off the tape for two seconds after the time and the average number read is stored in the array CALSE. Each calibration signal for each source is saved in this array which is used by VCAL to linearly extrapolate signal tape data to obtain calibrated data.

Subroutine READD is the master subroutine for processing data. This subroutine is called once for each set of data to be processed and controls the calling of other subroutines to create the final data. The effective radiated power is calculated by the one way range equation:

$$ERP_{dbm} = P_r + L + 20 \log R_N + 20 \log F_{MHz} + 37.8 - G_R - G_M$$

$$ERP_{dbw} = dbm - 30$$

P_r = power received (dbm)

L = line loss in receiving antenna (db)

R_N = slant range to aircraft (NM)

F_{MHz} = frequency (MHz)

G_R = gain of receiving antenna (db)

G_M = gain due to multipath radiation (db)

The data array created by READD is written to mass storage and the line printer.

Subroutine SIGNAL is called by CAL and READD to provide 0.5 seconds of averaged data off the signal tape for each source of data recorded. This subroutine returns uncalibrated data on each source.

Subroutine RADAR is called by READD to provide the slant range, horizontal range, aspect angle, and depression angle of the aircraft to the receiving antenna. The subroutine will use the average X, Y, Z location of the aircraft for 0.5 seconds interval and, through the subroutine PAMS, return the required data to READD.

Subroutine MULTPTH uses the technique described in appendix E to determine the effect of multipath radiation on the received signal. If the multipath option is selected, this subroutine will be called to return the db gain of the multipath signal at each data sample.

Two input tapes are required for the calculation of aircraft antenna patterns by ARPMP. These tapes are created by AFFTC/DOETD from an FM analog tape and an FPS-16 radar tape.

The first input tape is the digitized signal tape created from the FM analog signal tape. This tape is created in 16 bit words and is composed of three types of records. Function IWRD of ARPMP is used to extract the 16 bit words from the 60 bit words in the CDC 6500 computer.

The first record recorded on tape is the heading record. This record is used to identify the tape and has the format as shown in figure B15.

The second record written on tape is the time Cal record (figure B16). This record contains the tag number to identify the millisecond time in the data record. This tag number will be either a 177776_8 or 7_8 depending on the machine being used to create the tape.

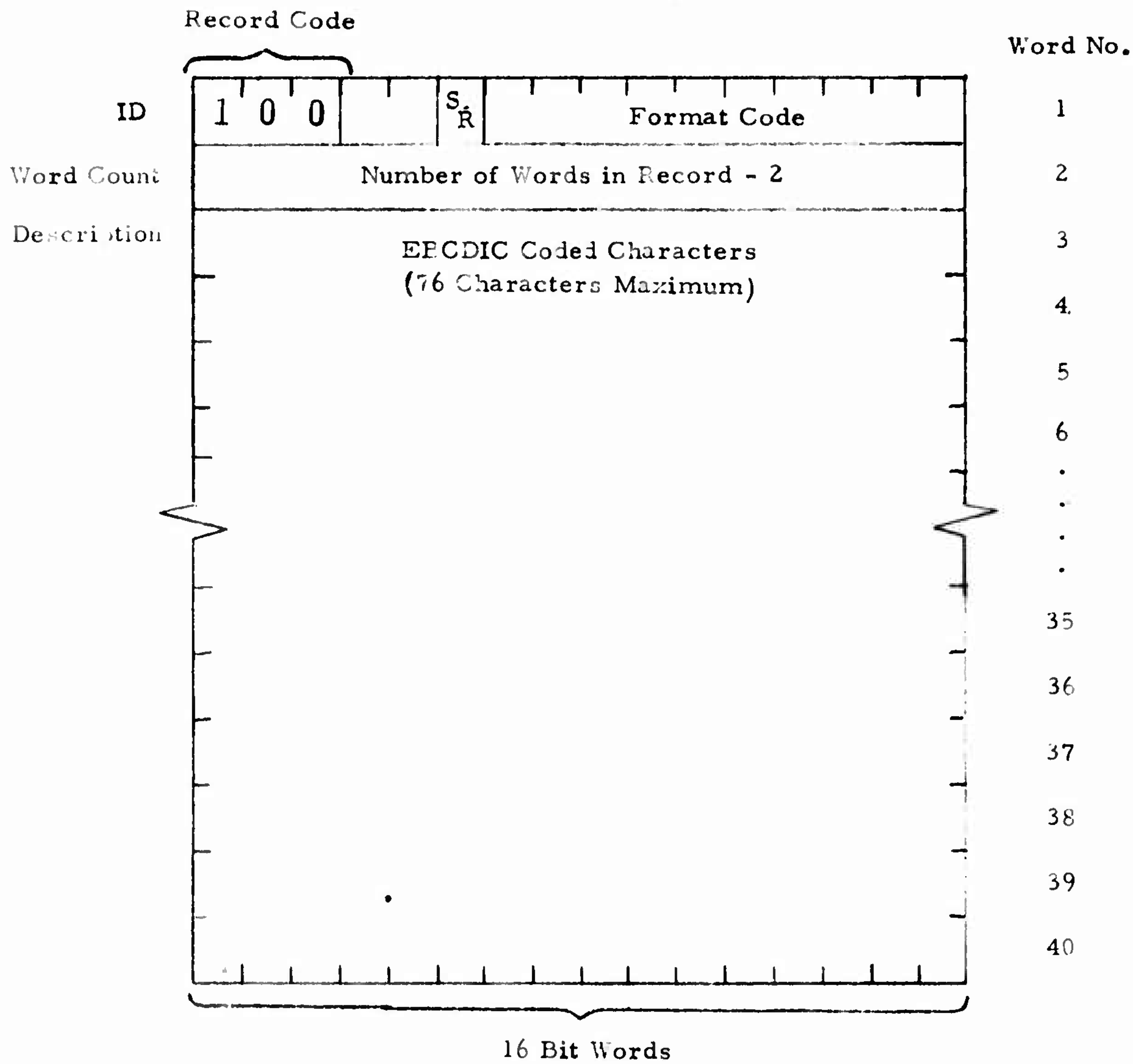
For each data source recorded on tape, an additional Cal record is written to identify the tag number to be associated with that data. All Cal records are read by ARPMP which reads the tag number to identify each data sample in the data record.

After the Cal records are written, the data records (figure B17) are written which contain data sampled at 0.1 second intervals off the FM tape. All data points are written in pairs of numbers in this record. The first number contains the data value and the second number contains the data tag number to identify what data is recorded. At every millisecond change a millisecond word is placed in the data record. This word is used to identify the time in the data record.

The second tape used by ARPMP is the radar tape. This tape is created by the Radar Computer Program as described by Range Data Processing System, FTC-TIM-73-2. The tape is composed of four different record types but only one record type is used by ARPMP. The first 13 words on record type 3 is used to provide the aircraft position relative to the receiving antenna. The format of this record is shown in figure B18.

The output tape created by ARPMP consists of records of 482 words which contains data in six word groups. For each data sample the following words are placed in the record: (1) source number, (2) signal strength (dbw), (3) depression angle (degrees), (4) aspect angle (degrees), (5) horizontal range (NM), and (6) time in total seconds. Word number 481 in the record contains the number of valid words in the record and word number 482 is set to 1 at the end of a data set.

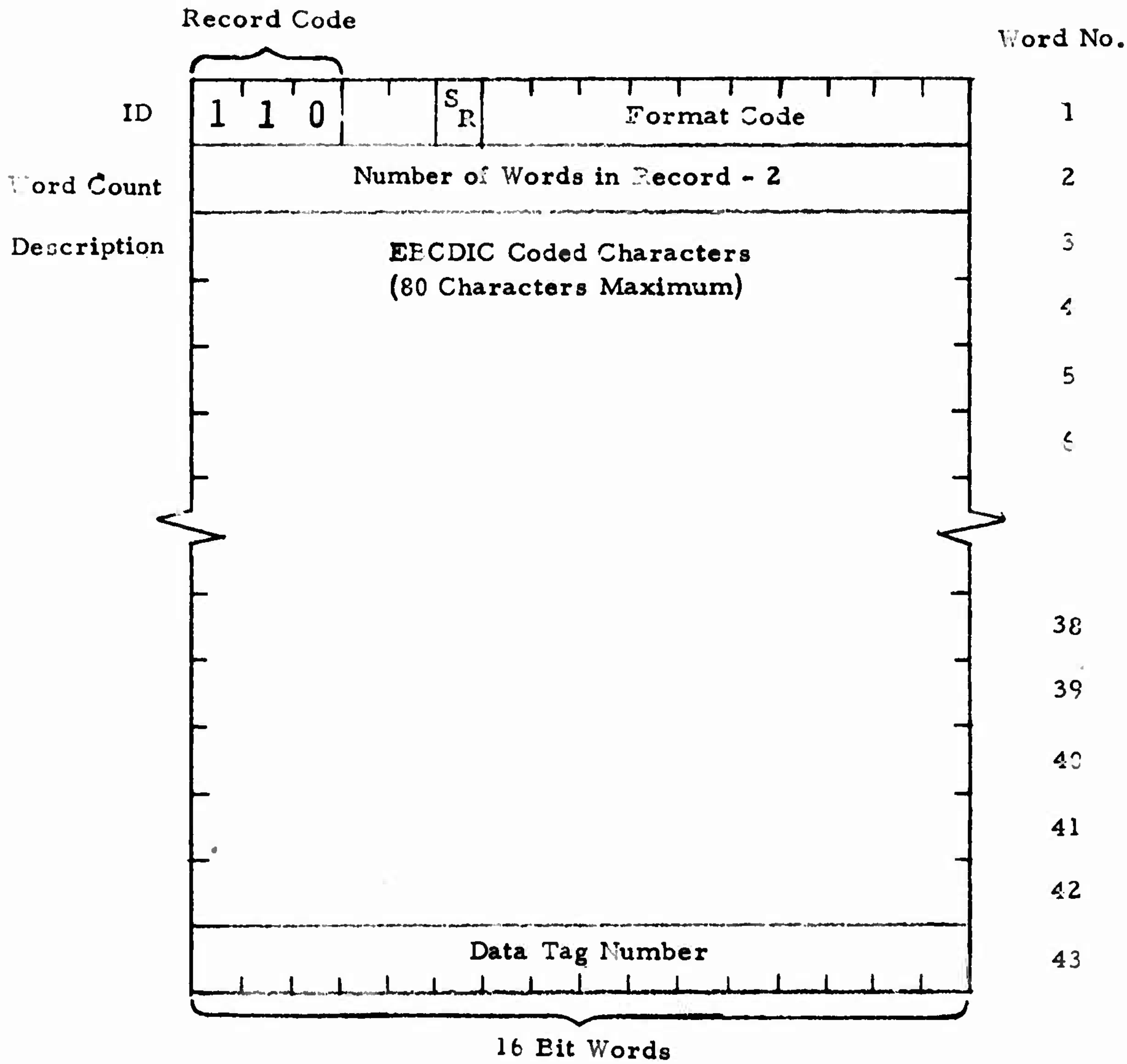
A listing of the ARPMP source deck can be found in appendix F.



SR = Source Number of Digitizing Equipment
(Not Used by ARPMP)

Format Code = EBCDIC Coded Format Identifying Character
(Not Used by ARPMP)

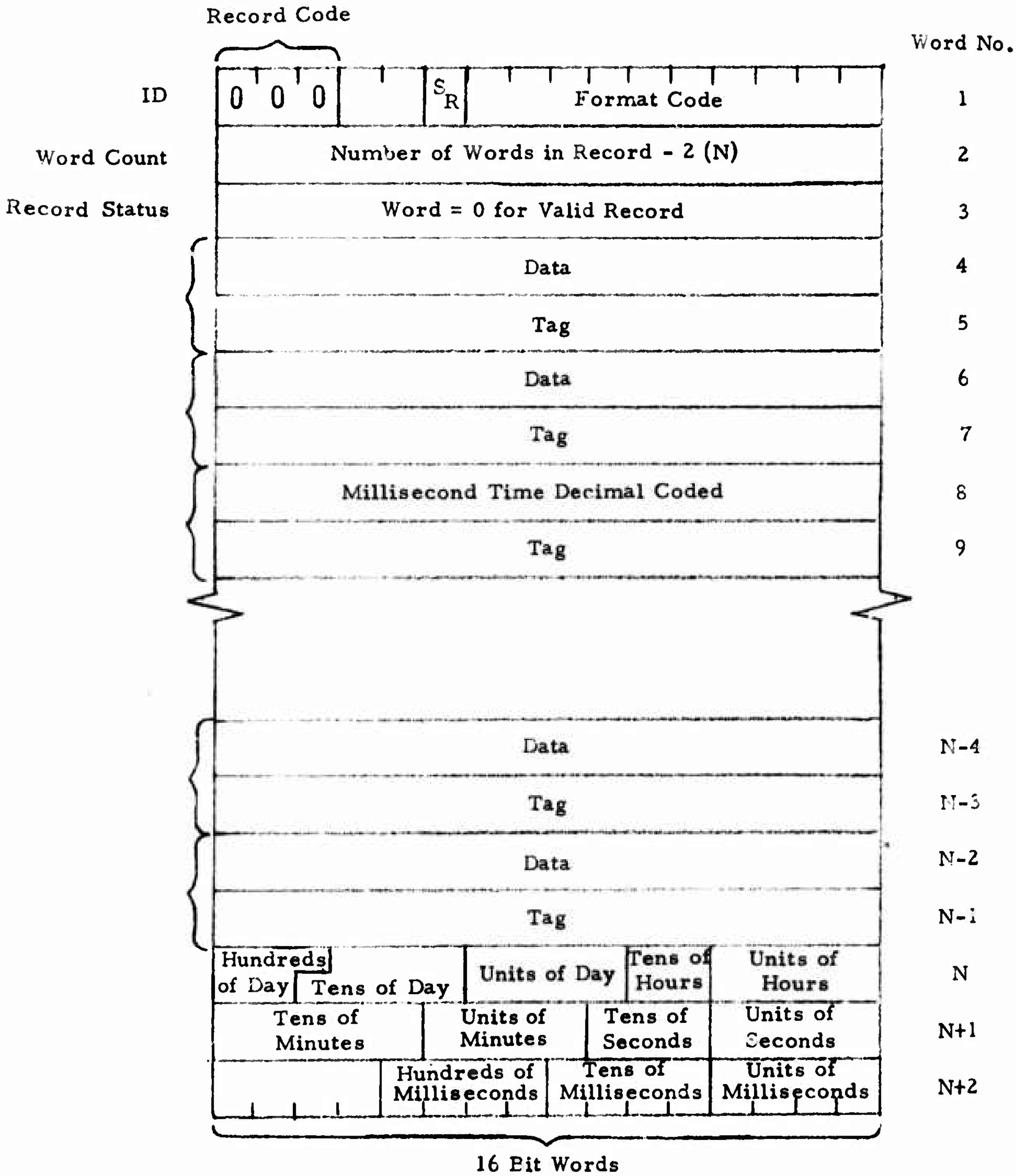
Figure B15 Heading Record Format



SR = Source Number of Digitizing Equipment
(Not Used by ARPMP)

Format Code = EBCDIC Coded Format Identifying Character
(Not Used by ARPMP)

Figure B16 Cal Record Format



SR = Source Number of Digitizing Equipment (Not Used by ARPMP)

Format Code = EBCDIC Coded Format Identifying Character (Not Used by ARPMP)

Millisecond Time Word is Placed at Each Millisecond Change in Record

Words N, N+1, and N+2 Represent Time of Last Data Word in Record

Figure B17 Data Record Format

WORD	CONTENTS	FORMAT
1	101	Integer
2	Total Time (Seconds)	Fp
3	Time (Hours)	Integer
4	Time (Minutes)	Integer
5	Time (Seconds)	Fp
6	Elapsed Time (Seconds)	Fp
7	Status Word For A Valid Record Equals '10H /'	A10
8	X (Feet North Of Antenna)	Fp
9	Y (Feet East Of Antenna)	Fp
10	Z (Feet Above Antenna)	Fp
11	DX/DT	Fp
12	DY/DT	Fp
13	DZ/DT	Fp

Figure B18 Radar Record Format

APPENDIX C

ANTENNA DATA ANALYSIS PROGRAM (ADAP)
Deck Number 4700

INTRODUCTION

The Antenna Data Analysis Program (ADAP) is designed to assist the Systems Engineer in planning, processing, and reducing data collected during antenna radiation pattern tests. To accomplish this, ADAP consists of a series of subroutines which can be used for: (1) predicting the effects of multipath radiation (MULT), (2) determining the permittivity which best eliminates the multipath radiation (MATCH), (3) merging radar tapes into one file (MERGE), and (4) plotting processed data on the Calcomp plotter (PLOT). Through the use of ADAP, data processed by the Antenna Radiation Pattern Measurement Program (ARPMP) can be plotted for use in final reports.

SYSTEM OVERVIEW

ADAP consists of a main program and 13 subprograms which are called to process the required data. Through the use of the main subroutines MPLOTS, RDMERGE, MULT, and MATCH each of the four available functions of ADAP can be executed (figure C1).

Mass storage input/output requirements for ADAP will depend upon the function being used. The mass storage requirements for each function are: (1) MULT - requires no mass storage, (2) MATCH - requires one input (TAPE11) mass storage file, (3) PLOT - requires one input (TAPE12) and one output (TAPE13) mass storage file, and (4) MERGE - requires one to three input (TAPE11, TAPE12, TAPE13) and one output (TAPE10) mass storage file.

The card input to ADAP consists of 11 different cards. The cards to be used for each run will depend upon the options of ADAP selected. A decision chart for the selection of the proper cards is shown in figure C2 and a description of the use of each card is presented in the Users Guide section of this appendix. Example deck structures, output listing, and plots are included to assist in the use of this data reduction program.

PREPARATION FOR USE

The program deck of ADAP will be stored with ARPMP on magnetic tape number 5540 in the tape library of building 3940. This tape will contain the following four files: (1) ADAP LGO (compiled file), (2) ARPMP LGO (compiled file), (3) ADAP source file, and (4) ARPMP source file. Prior to the use of the program the ADAP LGO file must be copied to disc as shown in figure C3. With the LGO file cataloged on disc it may be attached and executed.

USERS GUIDE

The execution of each function of ADAP is controlled by ADAP card 1 (figure C4). This card will select the option to be used by coding the proper name starting in column 1. When using the functions of ADAP,

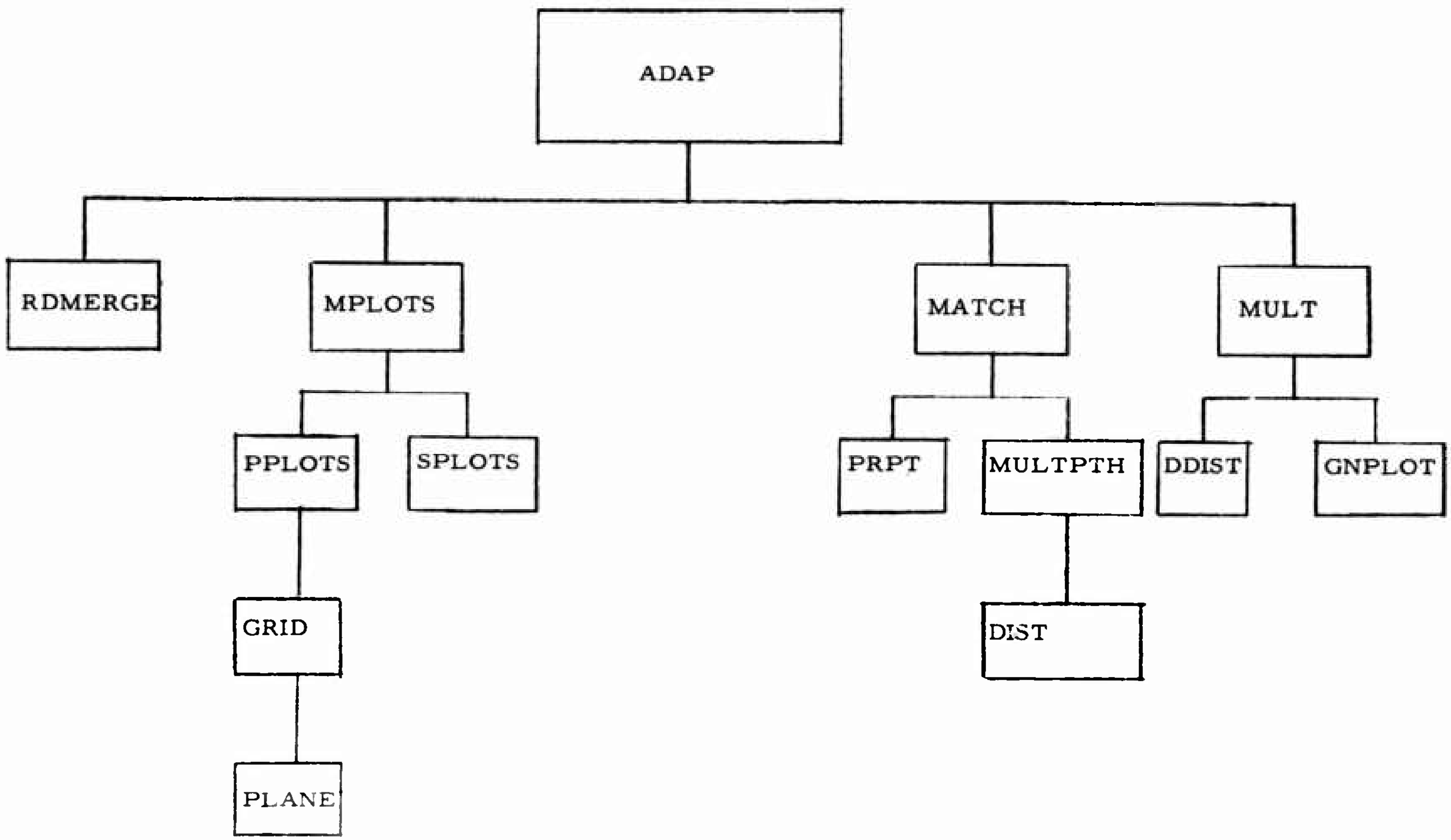


Figure C1 ADAP Block Diagram

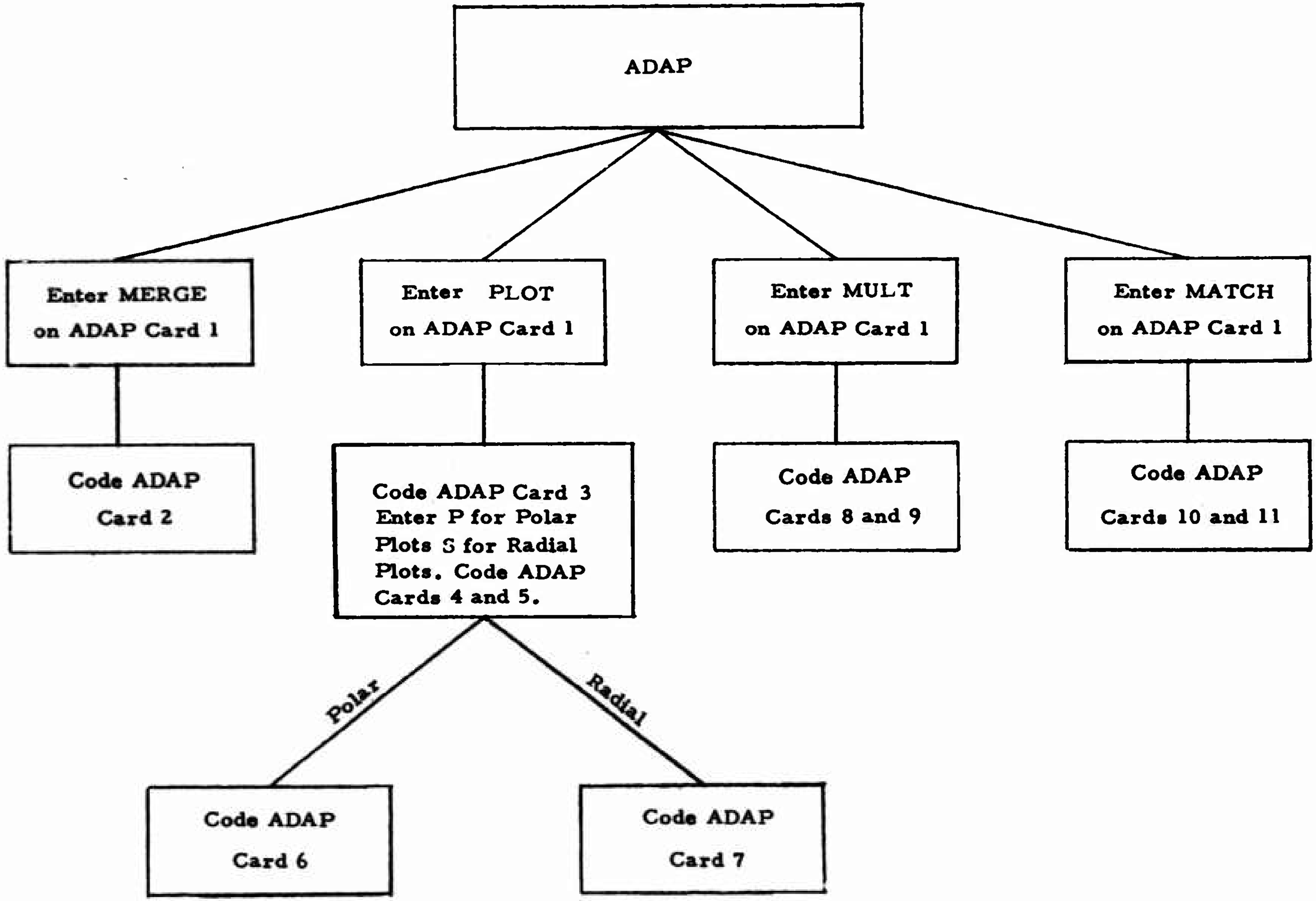
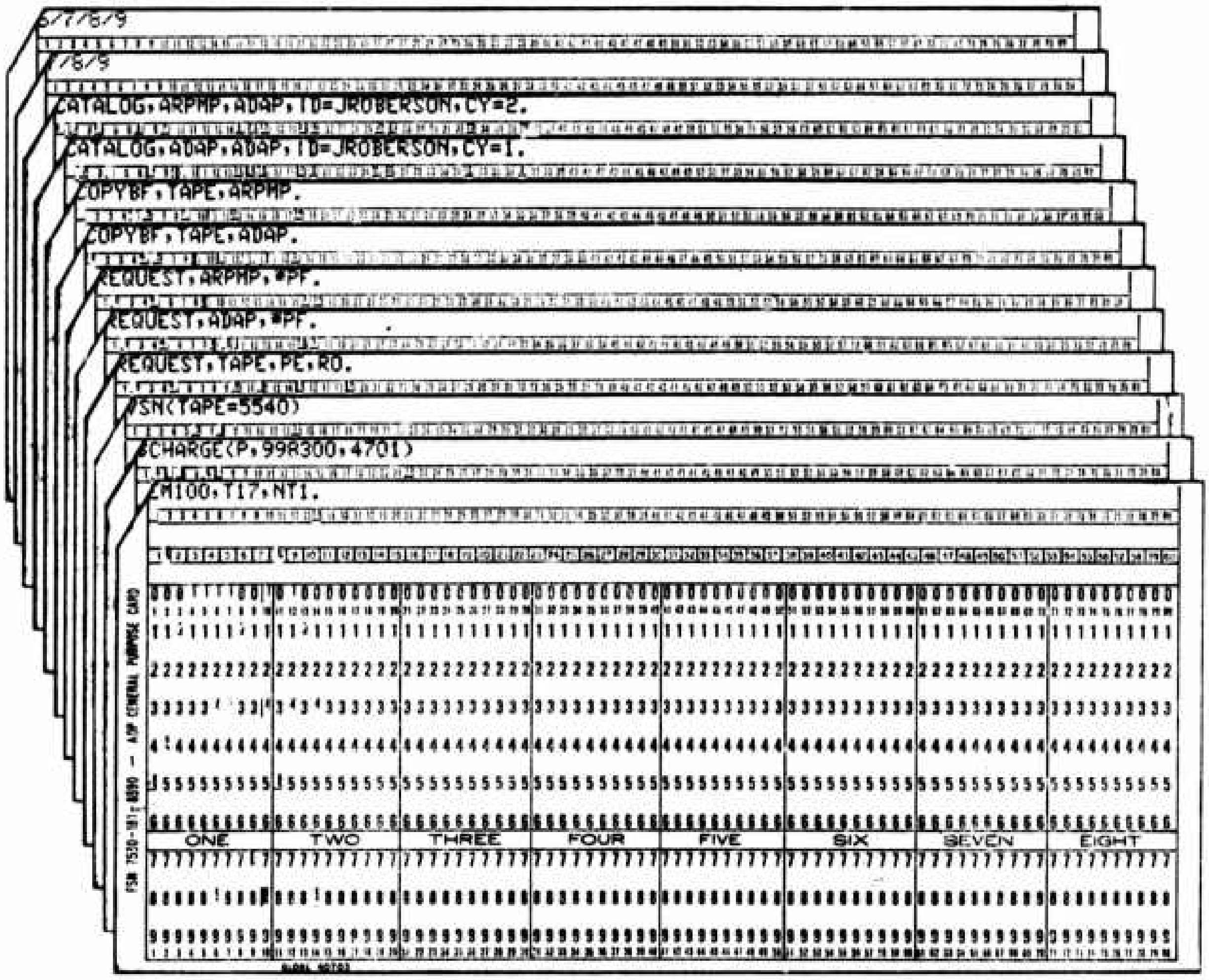


Figure C2 ADAP Decision Tree



Note: Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer

Figure C3 Deck Setup to Copy ARPMP and ADAP to Permanent File

Parameter Identification Card

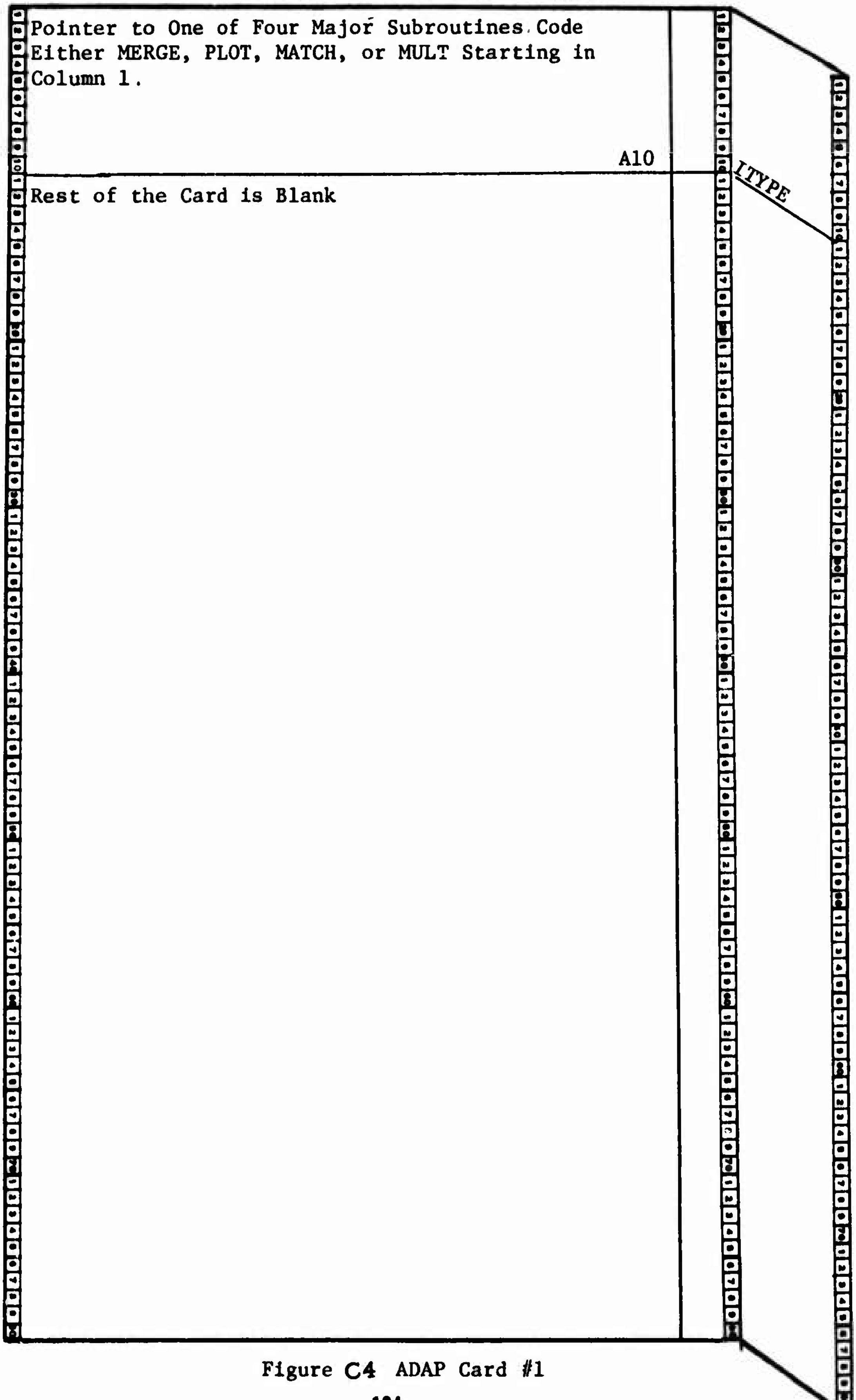


Figure C4 ADAP Card #1

care must be taken to insure the proper name is given to the mass storage files. Figure C5 lists the files required for each function of ADAP.

MERGE Function:

Execution of the MERGE function of ADAP, which combines radar tapes used by ARPMP, reduces the data storage requirement of radar data by 95 percent and reduces the computer execution time of ARPMP by about 50 percent. MERGE can be used to either store the radar data on disc or magnetic tape. Whenever possible, it is suggested that MERGE be used to store the radar data on disc, even for flights having only one radar tape, due to the savings of computer time and the elimination of the requirement for magnetic tape drives by ARPMP.

The only data card required, other than ADAP card 1, is ADAP card 2 (figure C6) with the number of tapes to be merged coded in column 10. When MERGE is used the tapes should be merged in order of increasing times with the tape having the lowest time on input file TAPE11. The merged data will be written on output file TAPE10. An example deck for MERGE is shown in figure C7.

PLOT Function:

The PLOT function of ADAP can produce either polar plots of the aircraft antenna pattern at selected depression angles or cartesian plots of range (NM) versus signal (effective radiated power dbw) of radial flight data. The input data is read from file name TAPE12 which was created by ARPMP. The output file is a Calcomp plot tape which is written to file name TAPE13. The printer listing created for the range plots contains all the data points used for the plot. The polar plot listing contains all the 0.5 degrees of aspect angles which contain data, the number of data samples in the aspect angle interval, average signal, and standard deviation of the data in the interval. Connecting lines will be drawn through all data points on the polar plots which are within five degrees in aspect angle. Example decks, listings, and plots are shown in figures C14 through C17.

When calling the PLOT function the first card coded is ADAP card 1 with PLOT and the second card coded is ADAP card 3 (figure C8). This card indicates the type of plots (P for polar and S for range) and the time interval to read data off the input file.

The third card coded is ADAP card 4 (figure C9). This card identifies the data to be processed and defines the scaling to be used on the plots. The first entry on the card is the source number of the data to be plotted. The source numbers are set by ARPMP and can be found in the ARPMP output listing.

The next items required on this card are the minimum and maximum values to be written on the signal axis scale. For polar plots, only the maximum value is required. For range plots the values should be picked such that [(maximum signal) - (minimum signal)] $\div$ Y axis length = 1, 2, or 4 x 10^N, where N is any integer number. This will insure the Y axis is scaled to an easily read value. The range interval is used only for range plots and should be set in the same manner as the signal interval.

FUNCTION	FILE NAME	DESCRIPTION
MULT	——	No mass storage files required.
MATCH	TAPE11	Input file created by ARPMP which contains radial flight data.
PLOT	TAPE12	Input file created by ARPMP which contains data to be plotted.
	TAPE13	Output file plot tape to be used by the Calcomp plotter.
MERGE	TAPE11	Input file radar tape to be merged or condensed. Contains the lowest times for merging.
	TAPE12	Second input tape for merging with TAPE11.
	TAPE13	Third input tape for merging with TAPE11 and TAPE12.
	TAPE10	Output file of merged or condensed radar tapes.

Figure C5 Mass Storage Files of ADAP

Parameter Identification Card

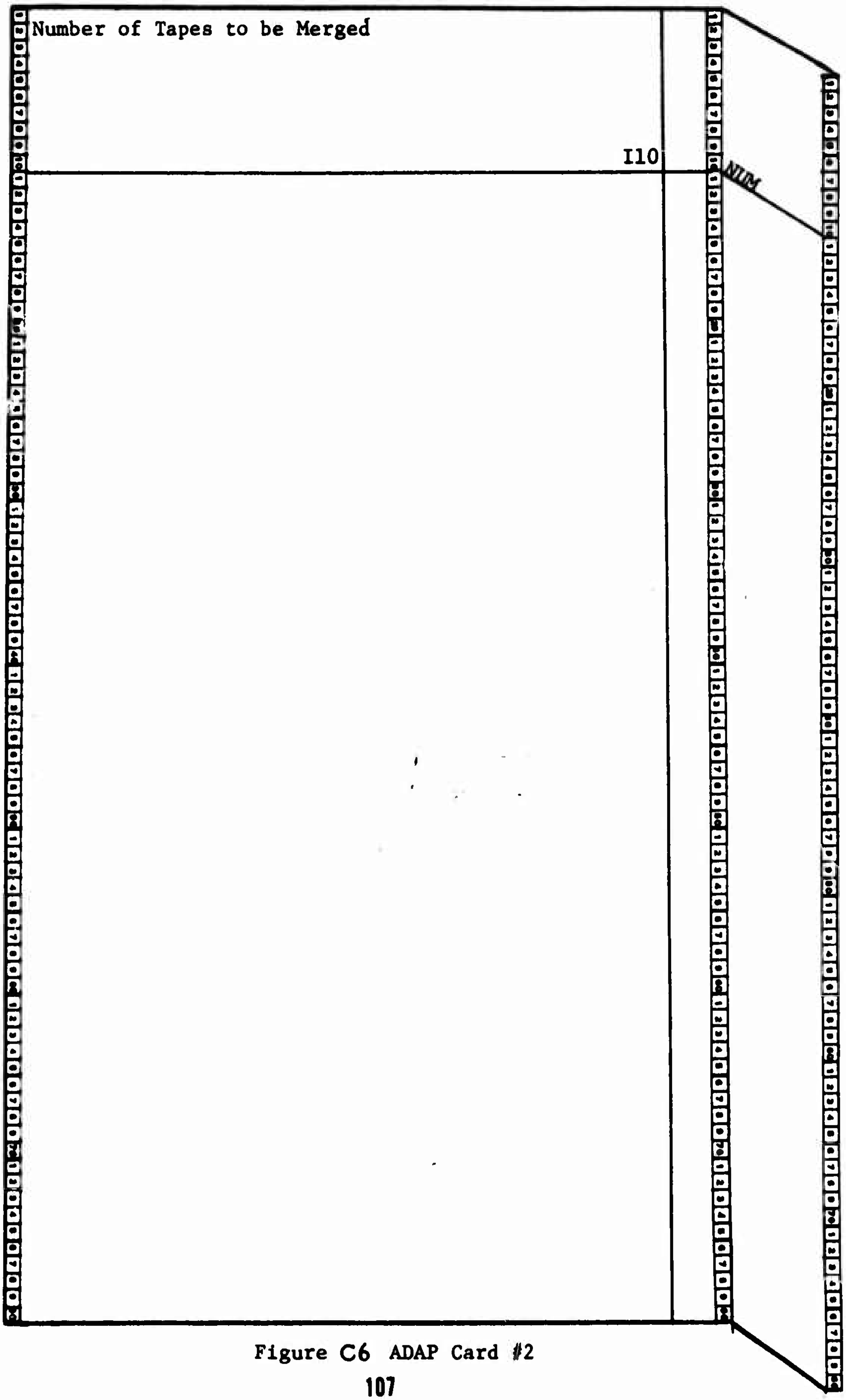
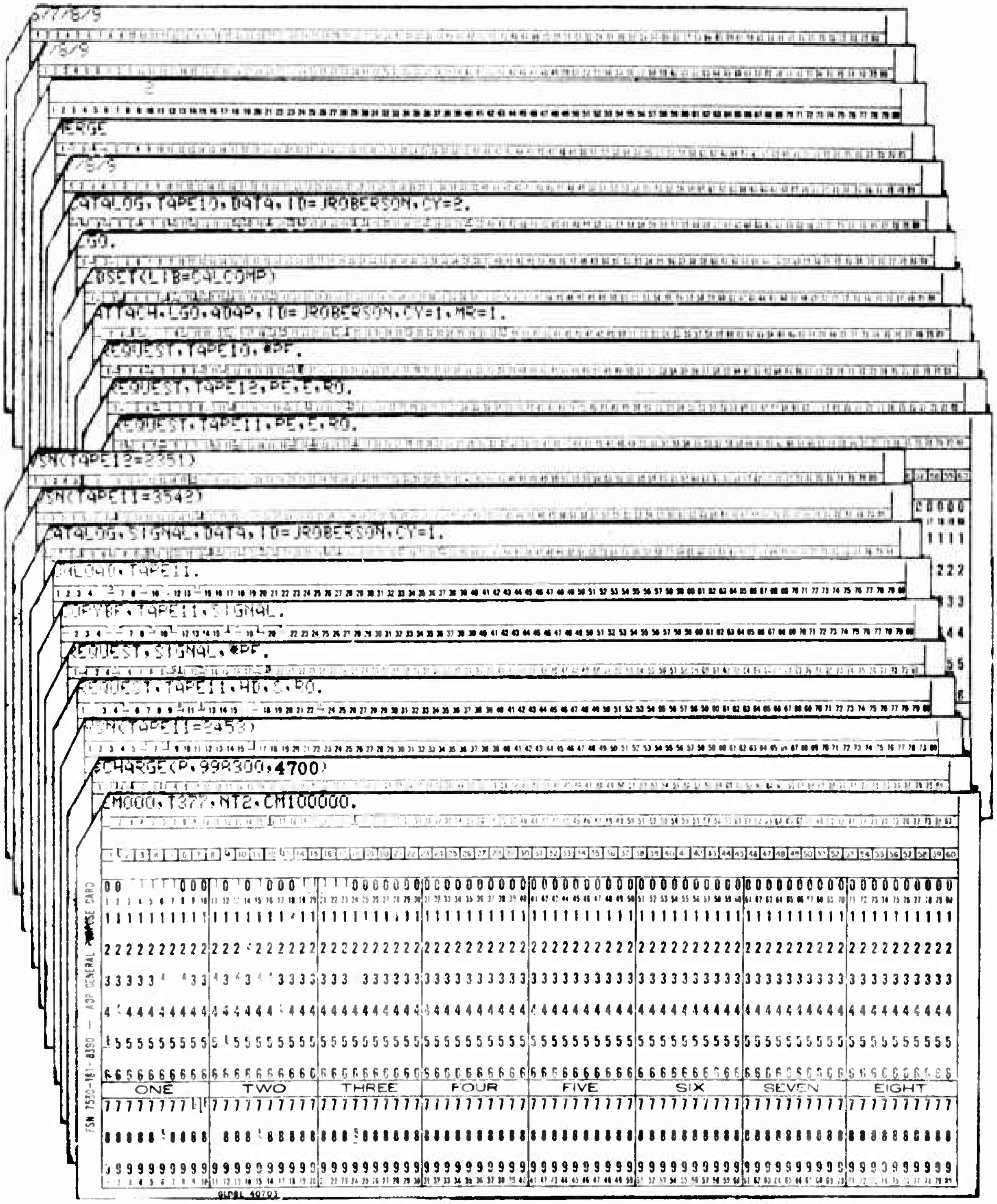


Figure C6 ADAP Card #2



Note: Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer

Figure C7 Example Deck for MERGE

The last two items on this card are the wild point check parameters. The minimum and maximum signals to be accepted and coded. Any signal which falls outside this interval is ignored by the program. This is used to insure data is not plotted which would be off the plot scale.

The fourth card required is a heading card (ADAP card 5 figure C10) which provides 70 columns of heading information to be printed on the listing and written on the plots. Information to identify the plots should be coded on this card.

The fifth card to be coded depends upon which plot routine is to be used. If range versus signal plots are to be produced, ADAP card 7 (figure C12) will be coded with the length of the X axis and Y axis. For polar plots ADAP card 6 (figure C11) is coded which contains the depression angle of the data to be plotted, scale interval, depression angle interval, type of plane to draw, and polar grid drawing code.

The polar plot will consist of all data which lies within the depression angle plus or minus the depression angle interval. If a 999.0 is coded, for the depression angle, all data will be plotted regardless of the actual depression angle.

The plane type should be set to a "1" to draw the airplane in the center of the plot. The paper selection should be set to a "1" if a polar grid is to be drawn on plain white plot paper or set to a "0" if polar grid paper is used. If the polar grid is to be drawn, the plotter request card should specify pen 2 as wet black and pen 1 as black ballpoint. Instructions should be given to center pen 1 on the perforations and to use 200 plain white paper. If polar paper is used, instructions should be given to center pen 1 in center of the polar paper (figure C13). Range plots should specify wet pen 1 black and paper 201 or 202.

ADAP cards 3 through 7 are repeated for each plot to be produced. Program PLOT will continue to produce plots until all data cards are read. Due to different plotter paper requirements polar plots and range versus signal plots cannot be created on the same run.

MULT Function:

The multipath radiation prediction option (MULT) of ADAP can be used for predicting the multipath effects to be expected at a given altitude and range. This program uses the technique presented in appendix E to calculate the multipath effects. Through the use of predicted multipath effects, the range and altitude can be determined such that the aircraft's flight path will avoid areas of signal cancellation. An example deck and output listing are shown in figures C18 and C19.

The first card coded should be ADAP card 1 with the MULT function selected. The second card coded will be ADAP card 8 (figure C20) with each altitude to be processed. A maximum of eight altitudes per run are permitted. For each altitude listed, a printer plot will be produced for each ADAP card 9.

The card that controls the number of plots to be produced is ADAP card 9 (figure C21). This card may be repeated as many times as desired. The entries required are range interval, receiving antenna height, frequency, polarization, permittivity, and conductivity. For ease in reading the printer plots, the range interval should be picked such that (maximum range - minimum range) ÷ 10 = 1, 2, or 5 x 10^N where N is any integer number. Frequency is recorded in MHz and polarization is equal to zero for horizontal or one for vertical. The relative permittivity and conductivity of the reflecting surface are entered as the last two items on the card.

MATCH Function:

The multipath matching option (MATCH) of ADAP can be used to determine the permittivity which produces the best elimination of the multipath effect. This program uses the output file created by ARPMP on a radial flight. The radial is corrected for multipath radiation by MATCH using the technique presented in appendix E. Due to inaccuracies in the calculation with high angle reflections, the program will not use data which has a reflection angle greater than 12 degrees. Through an iterative process MATCH will determine the permittivity which produces the multipath corrected radial with the least deviation from the data's mean. When this value is found the measured radial, multipath corrected radial, and predicted multipath effect are plotted on the line printer. An example deck and listing are shown in figures C24 and C25.

To run the MATCH option ADAP card 1 is coded with MATCH and ADAP card 10 (figure C22) is coded with an 80 column comment heading to print a heading on the output listing. ADAP card 11 (figure C23) should then be coded with the time interval, antenna height, aircraft altitude, frequency, and data tag number. This information will identify the data to be processed and parameters required to calculate the multipath effect.

Parameter Identification Card

Pointer to One of TWO Subroutines; Can be Either P; or S.			ITYPE
		3X	
Start Time	Hours	I2	IHR1
	Minutes	I2	MIN1
	Seconds	I2	ISEC1
		4X	
Stop Time	Hours	I2	IHR2
	Minutes	I2	MIN2
	Seconds	I2	ISEC2
The Rest of the Card is Blank			

Figure C8 ADAP Card #3

Parameter Identification Card

Field	Format	Variable
Source No. to be Plotted (Number as Set by Antenna Radiation Pattern Measurement Program)	F10.3	ATAG
Minimum Signal to be Plotted (dbw) (Left Blank for Polar Plots)	F10.3	MINSIG
Maximum Signal to be Plotted (dbw)	F10.3	MXSIG
Minimum Range to be Plotted (NM) (Left Blank for Polar Plots)	F10.3	MINRNG
Maximum Range to be Plotted (NM) (Left Blank for Polar Plots)	F10.3	MXRNG
Minimum Value Used for Wild Point Check of Signal	F10.3	RMINS
Maximum Value Used for Wild Point Check of Signal	F10.3	RMAXS
Left Blank		

Figure C9 ADAP Card #4

Parameter Identification Card

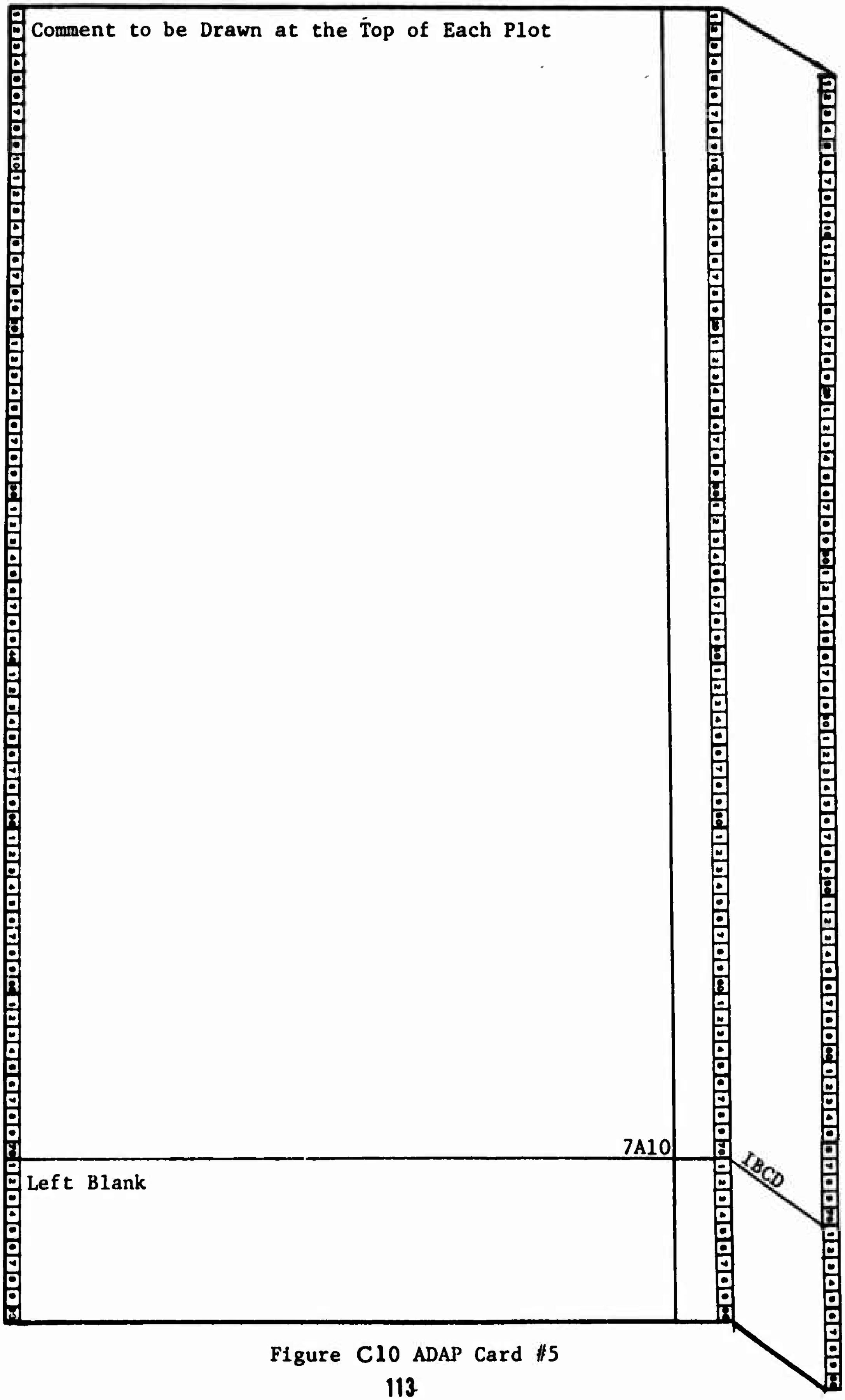


Figure C10 ADAP Card #5

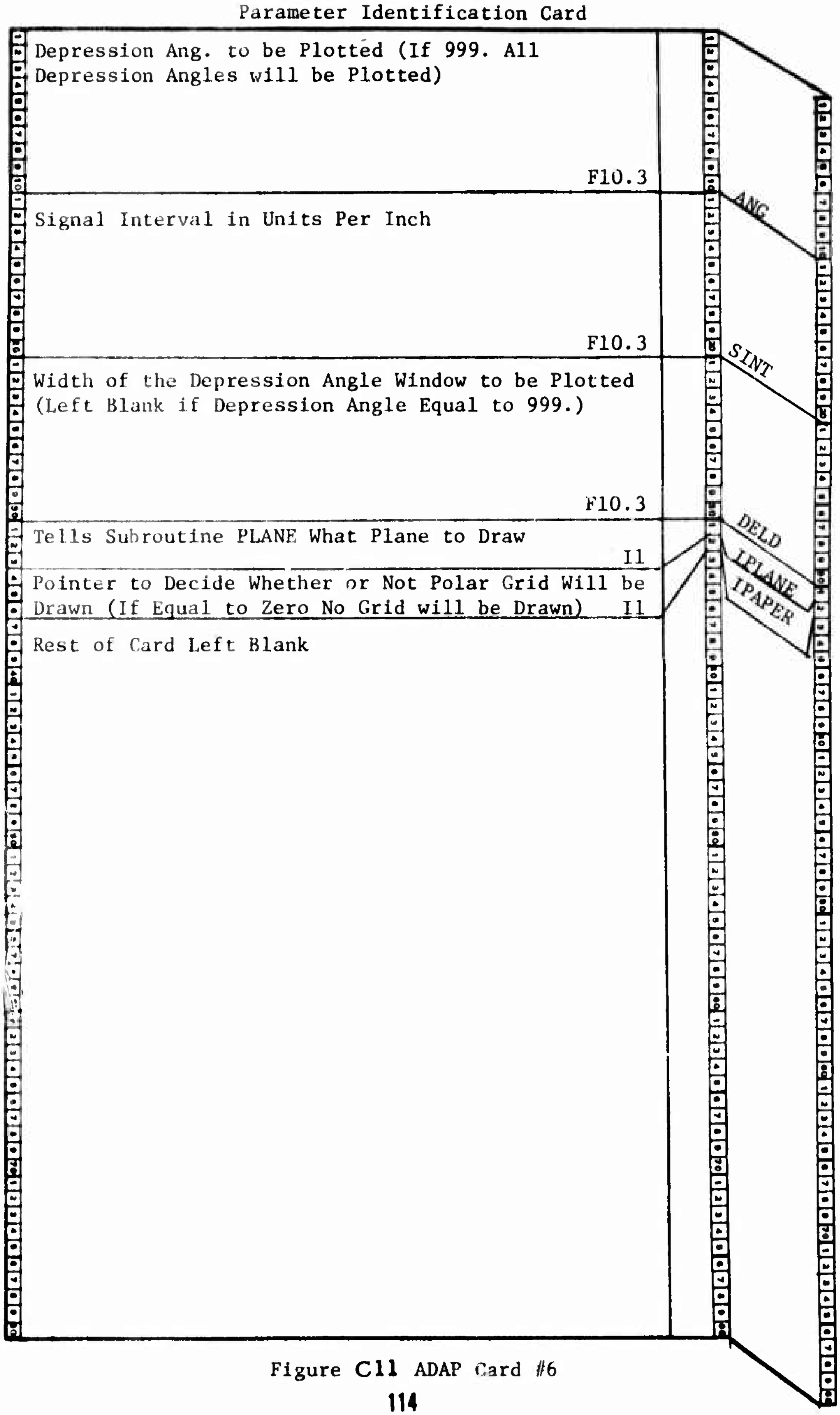


Figure C11 ADAP Card #6

Parameter Identication Card

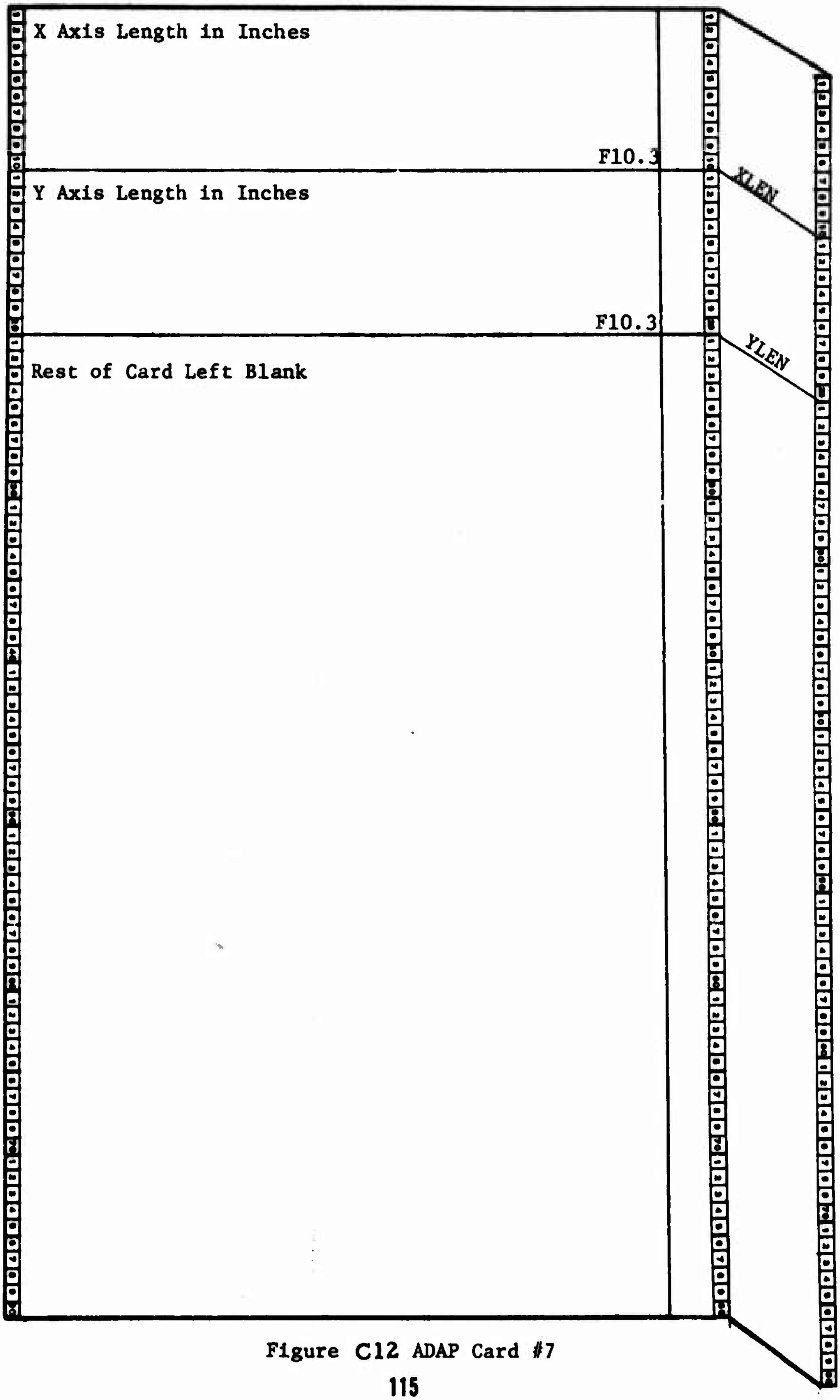


Figure C12 ADAP Card #7

EM	PLOTTER JOB REQUEST				
NAME John Doe			OFFICE SYMBOL DOEES	PHONE NUMBER 72475	JON 998300
TAPE NUMBER 3238	NUMBER OF PLOTS 4	NO. CY PER PLOT 1	TIME PER PLOT 2 1/2 Min	PLOT NUMBER START 1	END 999

PEN POS	TYPE PEN	COLOR INK	POINT SIZE		PRIORITY
[X] 1	wet	black		[X] PRODUCTION	
[ ] 2				[ ] CHECKOUT	
[ ] 3					

CLASSIFICATION		PROGRAMMER CALLED BEFORE PLOTTING	PAPER SIZE	
[ ] SHR	[ ] CONFIDENTIAL	[ ]	[ ] 200 PLAIN WHITE	[ ] 500 PLAIN WHITE
[ ] C. S.	[ ] SECRET		[ ] 201 OLIVE/10 DIV IN	[ ] 501 OLIVE/10 DIV IN
SPECIAL INSTRUCTIONS			[X] 202 RED/20 DIV IN	[ ] 502 RED/20 DIV IN
			[ ] 203 OLIVE/25 DIV IN	[ ] MISC

AFFTC FORM MAR 73 118 REPLACES AFFTC FORM 0-50, MAR 73, WHICH WILL BE USED

Sample Plot Request for Range Versus Signal Plots (Radial Flights)

EM	PLOTTER JOB REQUEST				
NAME John Doe			OFFICE SYMBOL DOEES	PHONE NUMBER 72475	JON 998300
TAPE NUMBER 3238	NUMBER OF PLOTS 10	NO. CY PER PLOT 1	TIME PER PLOT 2 1/2 Min	PLOT NUMBER START 1	END 999

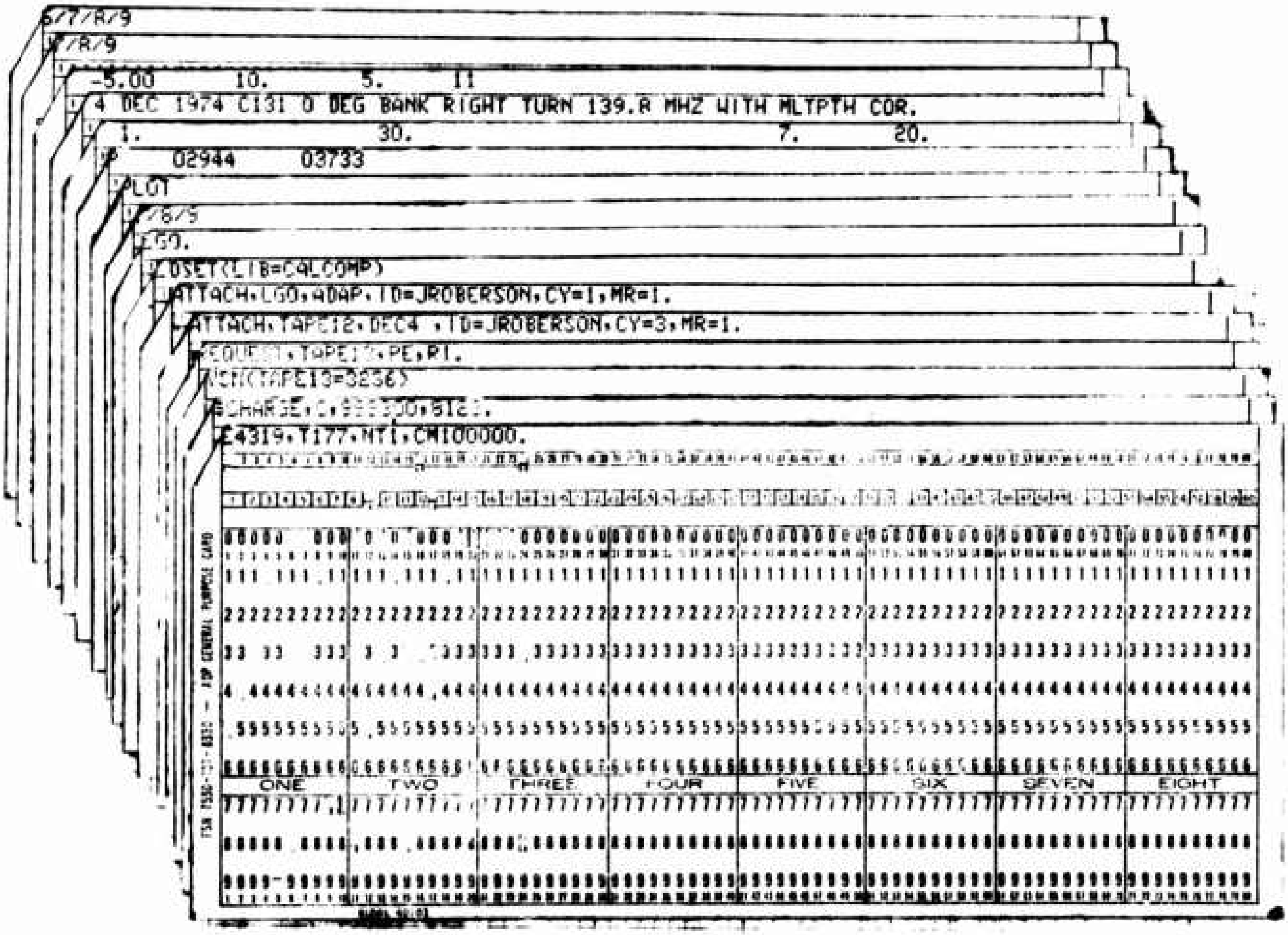
PEN POS	TYPE PEN	COLOR INK	POINT SIZE		PRIORITY
[X] 1	ball-point	black		[X] PRODUCTION	
[X] 2	wet	black		[ ] CHECKOUT	
3					

CLASSIFICATION		PROGRAMMER CALLED BEFORE PLOTTING	PAPER SIZE	
SHR	[ ] CONFIDENTIAL	[ ]	[X] 200 PLAIN WHITE	[ ] 500 PLAIN WHITE
C. S.	[ ] SECRET		[ ] 201 OLIVE/10 DIV IN	[ ] 501 OLIVE/10 DIV IN
SPECIAL INSTRUCTIONS Center pen #1 on perforations			[ ] 202 RED/20 DIV IN	[ ] 502 RED/20 DIV IN
			[ ] 203 OLIVE/25 DIV IN	[ ] MISC

AFFTC FORM MAR 73 118 REPLACES AFFTC FORM 0-50, MAR 73, WHICH WILL BE USED

Sample Plot Request for Polar Plots with Polar Grid Drawing Option

Figure C13 Sample Plotter Job Request Cards



Note: **Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer**

Figure [illegible] Example PLOT Deck

```
IF ITYPE = P, THEN POLAR PLOTS WILL BE PRODUCED
IF ITYPE = S, THEN RANGE VS. SIGNAL PLOTS WILL BE PRODUCED
THE START TIME IS   02944  THE STOP TIME IS   03733
 THE SOURCE NO. IS      1.000
THE MINIMUM SIGNAL TO BE PLOTTED IS       0.000 THE MAXIMUM SIGNAL IS     30.000
THE MINUMUM RANGE PLOTTED IS    -0.000 THE MAXIMUM RANGE PLOTTED IS     -0.000
DATA THAT IS  LESS THAN      7.000 OR GREATER THAN     20.000 WILL NOT BE PLOTTED
 ITYPE = P ; POLAR PLOTS WILL BE PRODUCED
```

Figure C15 Example PLOT Listing

4 DEC 1974 C131 0 DEG BANK RIGHT TURN 139.8 MHZ WITH MLTPTH COR.
714 POINTS TO BE PLOTTED
PLOTTED DATA FOR DEPRESSION ANGLE -5.000 PLUS OR MINUS 5.000 DEGS.
THE SIGNAL INTERVAL IS 10.000 IPLANE = 1

ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT
0.00	13.43	0.00	1.00	.50	13.36	.06	2.00	1.00	13.20	.12	2.00	1.50	13.47	0.00	1.00
2.00	12.99	.07	2.00	2.50	12.92	0.00	1.00	3.00	12.61	.04	2.00	3.50	12.77	.03	2.00
4.00	12.74	0.00	1.00	4.50	12.70	.06	2.00	5.00	12.45	.01	2.00	5.50	12.37	0.00	1.00
6.00	12.39	.36	2.00	6.50	12.24	.11	2.00	7.00	12.10	0.00	1.00	7.50	11.94	.07	2.00
8.00	11.65	0.00	1.00	8.50	11.69	.20	2.00	9.00	12.03	.06	2.00	9.50	12.04	0.00	1.00
10.00	12.11	0.00	1.00	10.50	12.04	.27	2.00	11.00	11.69	0.00	1.00	11.50	11.54	0.00	1.00
12.00	11.20	.00	2.00	12.50	11.45	0.00	1.00	13.00	11.51	.29	2.00	13.50	11.58	0.00	1.00
14.00	11.34	0.00	1.00	14.50	11.44	.33	2.00	15.00	11.70	0.00	1.00	15.50	11.39	0.00	1.00
16.00	11.75	.09	2.00	16.50	11.64	0.00	1.00	17.00	11.76	0.00	1.00	17.50	11.96	.11	2.00
18.00	12.00	0.00	1.00	18.50	12.13	.11	2.00	19.00	12.39	0.00	1.00	19.50	12.44	0.00	1.00
20.00	12.57	.08	2.00	20.50	12.85	0.00	1.00	21.00	12.83	0.00	1.00	21.50	13.04	.04	2.00
22.00	12.96	0.00	1.00	22.50	13.45	.25	2.00	23.00	13.44	0.00	1.00	23.50	13.64	0.00	1.00
24.00	13.69	0.00	1.00	24.50	13.85	.10	2.00	25.00	13.97	0.00	1.00	25.50	14.04	0.00	1.00
26.00	14.19	.08	2.00	26.50	14.60	0.00	1.00	27.00	14.38	0.00	1.00	27.50	14.37	.10	2.00
28.00	14.36	0.00	1.00	28.50	14.14	0.00	1.00	29.00	14.32	.21	2.00	29.50	14.21	0.00	1.00
30.00	14.29	0.00	1.00	30.50	14.32	.15	2.00	31.00	14.19	0.00	1.00	31.50	14.20	0.00	1.00
32.00	14.00	.29	2.00	32.50	13.71	0.00	1.00	33.00	13.74	0.00	1.00	33.50	13.70	0.00	1.00
34.00	13.65	.14	2.00	34.50	13.58	0.00	1.00	35.00	13.45	0.00	1.00	35.50	13.52	.06	2.00
36.00	13.31	0.00	1.00	36.50	13.71	0.00	1.00	37.00	13.24	.01	2.00	37.50	13.84	0.00	1.00
38.00	13.90	.44	2.00	38.50	13.76	0.00	1.00	39.00	14.00	.05	2.00	39.50	14.28	0.00	1.00
40.00	14.32	0.00	1.00	40.50	14.29	.30	2.00	41.00	14.20	0.00	1.00	41.50	14.31	.04	2.00
42.00	14.23	0.00	1.00	42.50	14.37	0.00	1.00	43.00	14.25	.03	2.00	43.50	14.21	0.00	1.00
44.00	14.27	.11	2.00	44.50	14.06	0.00	1.00	45.00	13.87	.16	2.00	45.50	13.75	0.00	1.00
46.00	13.97	0.00	1.00	46.50	13.77	0.00	1.00	47.00	13.79	0.00	1.00	47.50	13.79	.20	2.00
48.00	13.72	0.00	1.00	48.50	13.66	.01	2.00	49.00	13.50	0.00	1.00	49.50	13.77	0.00	1.00
50.00	13.56	.02	2.00	50.50	13.44	0.00	1.00	51.00	13.25	0.00	1.00	51.50	13.34	0.00	1.00
52.00	13.39	.10	2.00	52.50	12.98	0.00	1.00	53.00	13.13	0.00	1.00	53.50	12.90	0.00	1.00
54.00	12.66	0.00	1.00	54.50	12.80	.20	2.00	55.00	12.79	0.00	1.00	55.50	12.51	0.00	1.00
56.00	12.45	0.00	1.00	56.50	12.67	0.00	1.00	57.00	12.42	.05	2.00	57.50	12.65	0.00	1.00
58.00	12.65	0.00	1.00	58.50	12.85	0.00	1.00	59.00	13.07	0.00	1.00	59.50	12.99	0.00	1.00
60.00	13.34	.19	2.00	60.50	13.41	0.00	1.00	61.00	13.83	0.00	1.00	61.50	13.99	0.00	1.00
62.00	14.21	0.00	1.00	62.50	14.64	.08	2.00	63.00	14.93	0.00	1.00	63.50	15.13	0.00	1.00
64.00	15.20	0.00	1.00	64.50	15.31	0.00	1.00	65.00	15.47	.00	2.00	65.50	15.31	0.00	1.00
66.00	15.40	0.00	1.00	66.50	15.27	0.00	1.00	67.00	14.79	0.00	1.00	67.50	14.88	.12	2.00
68.00	15.06	0.00	1.00	68.50	14.47	0.00	1.00	69.00	14.30	0.00	1.00	69.50	14.17	0.00	1.00
70.00	14.05	.23	2.00	70.50	13.80	0.00	1.00	71.00	13.93	0.00	1.00	71.50	13.56	0.00	1.00
72.00	13.50	0.00	1.00	72.50	13.16	.39	2.00	73.00	12.67	0.00	1.00	73.50	12.78	0.00	1.00
74.00	12.51	0.00	1.00	74.50	12.48	0.00	1.00	75.00	12.71	.07	2.00	75.50	12.84	0.00	1.00
76.00	12.62	0.00	1.00	76.50	12.34	0.00	1.00	77.00	12.54	.06	2.00	77.50	12.39	0.00	1.00
78.00	12.54	0.00	1.00	78.50	12.53	.02	2.00	79.00	12.63	0.00	1.00	79.50	12.75	.01	2.00
80.00	12.74	0.00	1.00	80.50	12.68	0.00	1.00	81.00	12.63	.00	2.00	81.50	12.52	0.00	1.00
82.00	12.60	0.00	1.00	82.50	12.75	.02	2.00	83.00	12.65	0.00	1.00	83.50	12.48	.14	2.00
84.00	12.55	0.00	1.00	84.50	12.40	0.00	1.00	85.00	12.75	.34	2.00	85.50	12.58	0.00	1.00
86.00	12.92	.05	2.00	86.50	12.82	0.00	1.00	87.00	13.21	0.00	1.00	87.50	13.50	.14	2.00
88.00	13.71	0.00	1.00	88.50	13.47	0.00	1.00	89.00	13.84	.12	2.00	89.50	13.71	0.00	1.00
90.00	13.86	.12	2.00	90.50	13.90	0.00	1.00	91.00	13.90	0.00	1.00	91.50	13.98	.06	2.00
92.00	13.85	0.00	1.00	92.50	13.84	.01	2.00	93.00	13.83	0.00	1.00	93.50	13.98	0.00	1.00
94.00	13.82	.05	2.00	94.50	13.71	0.00	1.00	95.00	13.54	0.00	1.00	95.50	13.59	.02	2.00
96.00	13.49	0.00	1.00	96.50	13.27	.16	2.00	97.00	12.98	0.00	1.00	97.50	12.80	0.00	1.00
98.00	12.58	.15	2.00	98.50	12.03	0.00	1.00	99.00	11.83	.13	2.00	99.50	11.83	0.00	1.00

Figure C15 (Continued)

4 DEC 1974 C131 0 DEG BANK RIGHT TURN 139.8 MHZ WITH MLTPTH COR.
714 POINTS TO BE PLOTTED
PLOTTED DATA FOR DEPRESSION ANGLE -5.000 PLUS OR MINUS 5.000 DEGS.
THE SIGNAL INTERVAL IS 10.000 IPLANE = 1

ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT
100.00	11.41	0.00	1.00	100.50	11.25	.19	2.00	101.00	11.29	0.00	1.00	101.50	11.16	0.00	1.00
102.00	11.12	.06	2.00	102.50	11.13	0.00	1.00	103.00	10.93	0.00	1.00	103.50	10.93	.03	2.00
104.00	10.99	0.00	1.00	104.50	11.14	0.00	1.00	105.00	11.38	0.00	1.00	105.50	11.75	.18	2.00
106.00	11.68	0.00	1.00	106.50	11.33	0.00	1.00	107.00	11.95	0.00	1.00	107.50	11.95	0.00	1.00
108.00	11.98	.01	2.00	108.50	12.14	0.00	1.00	109.00	11.52	0.00	1.00	109.50	12.06	0.00	1.00
110.00	11.97	0.00	1.00	110.50	12.09	.08	2.00	111.00	12.34	0.00	1.00	111.50	12.08	0.00	1.00
112.00	12.25	0.00	1.00	112.50	12.38	0.00	1.00	113.00	12.20	.25	2.00	113.50	12.50	0.00	1.00
114.00	12.56	0.00	1.00	114.50	14.04	0.00	1.00	115.50	11.57	.17	2.00	116.00	12.58	0.00	1.00
116.50	12.31	0.00	1.00	117.00	12.03	0.00	1.00	117.50	11.94	.76	2.00	118.00	11.73	0.00	1.00
118.50	11.91	.05	2.00	119.00	11.54	0.00	1.00	119.50	12.17	0.00	1.00	120.00	12.16	.28	2.00
120.50	12.20	0.00	1.00	121.00	12.22	0.00	1.00	121.50	12.16	.14	2.00	122.00	12.10	0.00	1.00
122.50	12.26	0.00	1.00	123.00	12.35	.05	2.00	123.50	12.23	0.00	1.00	124.00	11.70	.41	2.00
124.50	11.80	0.00	1.00	125.00	11.55	0.00	1.00	125.50	11.63	.34	2.00	126.00	11.01	0.00	1.00
126.50	11.16	0.00	1.00	127.00	10.67	.12	2.00	127.50	10.97	0.00	1.00	128.00	10.64	0.00	1.00
128.50	10.76	.12	2.00	129.00	10.46	0.00	1.00	129.50	10.13	0.00	1.00	130.00	10.29	.17	2.00
130.50	10.84	0.00	1.00	131.00	10.61	0.00	1.00	131.50	10.74	.03	2.00	132.00	10.05	0.00	1.00
132.50	10.15	0.00	1.00	133.00	10.45	.28	2.00	133.50	10.57	0.00	1.00	134.00	11.36	0.00	1.00
134.50	10.92	.26	2.00	135.00	11.14	0.00	1.00	135.50	11.22	0.00	1.00	136.00	11.27	.05	2.00
136.50	10.98	0.00	1.00	137.00	11.09	0.00	1.00	137.50	10.96	.03	2.00	138.00	10.47	0.00	1.00
138.50	11.03	0.00	1.00	139.00	11.36	.40	2.00	139.50	10.93	0.00	1.00	140.00	10.07	0.00	1.00
140.50	10.67	.13	2.00	141.00	10.84	0.00	1.00	141.50	10.32	0.00	1.00	142.00	10.33	.22	2.00
142.50	10.29	0.00	1.00	143.00	11.45	0.00	1.00	143.50	10.94	.04	2.00	144.00	11.29	0.00	1.00
144.50	11.30	.15	2.00	145.00	11.49	0.00	1.00	145.50	11.20	.04	2.00	146.00	11.27	0.00	1.00
146.50	11.79	0.00	1.00	147.00	11.11	.01	2.00	147.50	11.90	0.00	1.00	148.00	11.75	.54	2.00
148.50	11.40	0.00	1.00	149.00	11.52	.04	2.00	149.50	11.08	0.00	1.00	150.00	11.47	.21	2.00
150.50	10.77	0.00	1.00	151.00	11.05	0.00	1.00	151.50	10.72	.20	2.00	152.00	10.68	0.00	1.00
152.50	10.76	.13	2.00	153.00	10.57	0.00	1.00	153.50	10.07	.19	2.00	154.00	10.57	0.00	1.00
154.50	10.10	0.00	1.00	155.00	9.76	.19	2.00	155.50	9.97	0.00	1.00	156.00	9.40	.05	2.00
156.50	9.77	0.00	1.00	157.00	9.48	0.00	1.00	157.50	9.97	0.00	1.00	158.00	9.86	.23	2.00
158.50	9.84	0.00	1.00	159.00	10.16	0.00	1.00	159.50	9.85	0.00	1.00	160.00	10.25	0.00	1.00
160.50	10.68	0.00	1.00	161.00	10.65	0.00	1.00	161.50	10.97	0.00	1.00	162.00	11.03	0.00	1.00
162.50	11.17	.37	2.00	163.00	11.07	0.00	1.00	163.50	10.80	0.00	1.00	164.00	12.00	0.00	1.00
164.50	11.24	0.00	1.00	165.00	10.71	0.00	1.00	165.50	11.62	0.00	1.00	166.00	11.79	0.00	1.00
166.50	10.52	0.00	1.00	167.00	11.67	0.00	1.00	167.50	11.75	0.00	1.00	168.00	11.18	.21	2.00
168.50	11.15	0.00	1.00	169.00	10.86	0.00	1.00	169.50	10.97	0.00	1.00	170.00	11.17	0.00	1.00
170.50	11.87	0.00	1.00	171.00	11.40	0.00	1.00	171.50	11.32	0.00	1.00	172.00	11.87	.36	2.00
172.50	11.23	0.00	1.00	173.00	11.33	.06	2.00	173.50	11.40	0.00	1.00	174.00	11.89	.06	2.00
174.50	11.70	0.00	1.00	175.00	11.64	.01	2.00	175.50	11.27	0.00	1.00	176.00	11.99	.23	2.00
176.50	11.92	0.00	1.00	177.00	12.03	.22	2.00	177.50	11.69	0.00	1.00	178.00	11.77	.07	2.00
178.50	11.54	0.00	1.00	179.00	11.71	.14	2.00	179.50	12.59	0.00	1.00	180.00	12.56	0.00	1.00
180.50	11.81	.38	2.00	181.00	11.87	0.00	1.00	181.50	12.49	0.00	1.00	182.00	12.22	0.00	1.00
182.50	12.90	.60	2.00	183.00	12.04	0.00	1.00	183.50	12.56	.13	2.00	184.00	12.92	0.00	1.00
184.50	12.31	0.00	1.00	185.00	12.26	.29	2.00	185.50	12.77	0.00	1.00	186.00	13.39	.32	2.00
186.50	11.90	0.00	1.00	189.50	12.70	.64	2.00	190.00	12.92	0.00	1.00	190.50	12.30	.75	2.00
191.00	11.57	0.00	1.00	191.50	11.36	0.00	1.00	192.00	11.54	.54	2.00	192.50	11.21	0.00	1.00
193.00	11.38	0.00	1.00	193.50	12.17	.55	2.00	194.00	11.22	0.00	1.00	194.50	10.99	0.00	1.00
195.00	11.05	.09	2.00	195.50	10.89	0.00	1.00	196.00	10.86	0.00	1.00	196.50	11.15	.01	2.00
197.00	11.43	0.00	1.00	197.50	11.14	0.00	1.00	198.00	11.19	.09	2.00	198.50	10.84	0.00	1.00
199.00	11.05	0.00	1.00	199.50	11.73	.07	2.00	200.00	11.46	0.00	1.00	200.50	11.83	0.00	1.00
201.00	12.02	0.00	1.00	201.50	12.08	.37	2.00	202.00	12.42	0.00	1.00	202.50	11.91	0.00	1.00

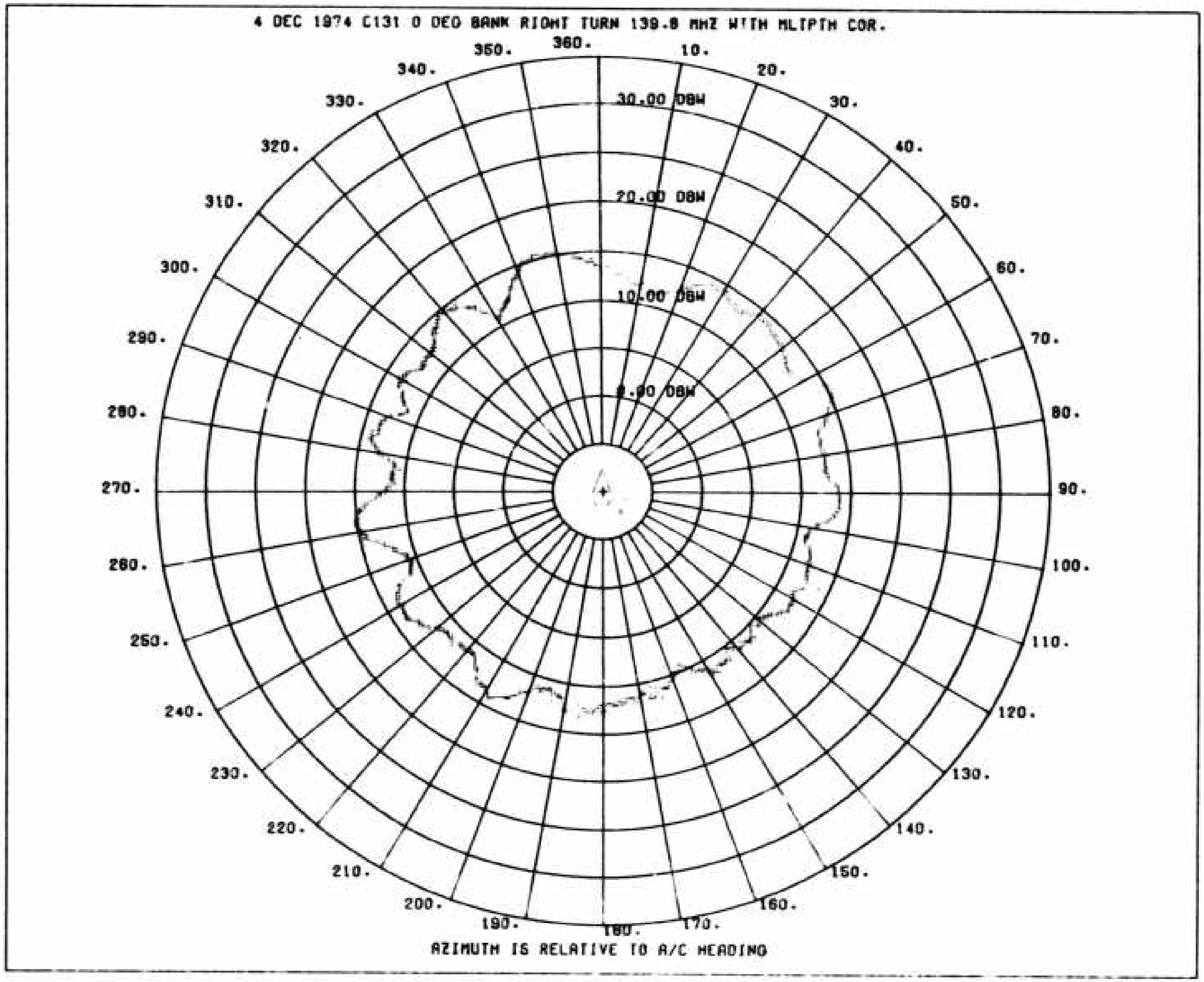
Figure C15 (Continued)

4 DEC 1974 C131 0 DEG BANK RIGHT TURN 139.8 MHZ WITH MLTPTH COR.
714 POINTS TO BE PLOTTED
PLOTTED DATA FOR DEPRESSION ANGLE -5.000 PLUS OR MINUS 5.000 DEGS.
THE SIGNAL INTERVAL IS 10.000 IPLANE = 1

ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT	ASP ANG	SIGNAL	STDEV	COUNT
203.00	12.66	.60	2.00	203.50	12.64	0.00	1.00	204.00	13.22	0.00	1.00	204.50	13.24	.05	2.00
205.00	13.17	0.00	1.00	205.50	13.32	0.00	1.00	206.00	13.44	.06	2.00	206.50	13.53	0.00	1.00
207.00	13.62	0.00	1.00	207.50	13.75	.25	2.00	208.00	13.90	0.00	1.00	208.50	14.19	0.00	1.00
209.00	14.03	.09	2.00	209.50	13.67	0.00	1.00	210.00	13.40	0.00	1.00	210.50	13.27	.13	2.00
211.00	13.30	0.00	1.00	211.50	13.34	0.00	1.00	212.00	13.27	.32	2.00	212.50	13.26	0.00	1.00
213.00	13.23	0.00	1.00	213.50	13.69	.59	2.00	214.00	12.99	0.00	1.00	214.50	12.28	0.00	1.00
215.00	12.11	.55	2.00	215.50	12.23	0.00	1.00	216.00	12.00	0.00	1.00	216.50	11.53	.25	2.00
217.00	11.47	0.00	1.00	217.50	11.13	0.00	1.00	218.00	11.19	.07	2.00	218.50	11.11	0.00	1.00
219.00	11.19	0.00	1.00	219.50	10.99	0.00	1.00	220.00	11.19	.04	2.00	220.50	11.34	0.00	1.00
221.00	11.33	0.00	1.00	221.50	11.32	.01	2.00	222.00	11.26	0.00	1.00	222.50	11.32	0.00	1.00
223.00	11.11	0.00	1.00	223.50	11.50	0.00	1.00	224.00	11.89	0.00	1.00	224.50	11.66	0.00	1.00
225.00	11.79	0.00	1.00	225.50	11.14	.34	2.00	226.00	11.63	0.00	1.00	226.50	11.29	0.00	1.00
227.00	11.35	0.00	1.00	227.50	11.30	0.00	1.00	228.00	11.52	0.00	1.00	228.50	11.51	0.00	1.00
229.00	11.72	0.00	1.00	229.50	11.59	.02	2.00	230.00	11.63	0.00	1.00	230.50	11.78	0.00	1.00
231.00	12.55	0.00	1.00	231.50	12.21	0.00	1.00	232.00	12.53	0.00	1.00	232.50	12.79	0.00	1.00
233.00	12.76	0.00	1.00	233.50	12.95	.04	2.00	234.00	12.81	0.00	1.00	234.50	12.96	0.00	1.00
235.00	12.97	0.00	1.00	235.50	13.47	0.00	1.00	236.00	13.55	0.00	1.00	236.50	13.68	0.00	1.00
237.00	13.63	0.00	1.00	237.50	13.60	0.00	1.00	238.00	13.53	.06	2.00	238.50	13.58	0.00	1.00
239.00	13.49	0.00	1.00	239.50	13.36	0.00	1.00	240.00	13.35	0.00	1.00	240.50	13.65	.12	2.00
241.00	13.73	0.00	1.00	241.50	13.20	0.00	1.00	242.00	13.55	0.00	1.00	242.50	13.43	0.00	1.00
243.00	13.01	.16	2.00	243.50	13.25	0.00	1.00	244.00	12.59	0.00	1.00	244.50	12.69	0.00	1.00
245.00	12.78	0.00	1.00	245.50	12.05	.25	2.00	246.00	11.34	0.00	1.00	246.50	10.94	0.00	1.00
247.00	10.96	0.00	1.00	247.50	11.02	0.00	1.00	248.00	10.84	.28	2.00	248.50	10.75	0.00	1.00
249.00	10.55	0.00	1.00	249.50	10.42	0.00	1.00	250.00	10.88	0.00	1.00	250.50	10.76	0.00	1.00
251.00	10.79	.08	2.00	251.50	10.89	0.00	1.00	252.00	11.04	0.00	1.00	252.50	11.30	0.00	1.00
253.00	11.49	0.00	1.00	253.50	11.96	.20	2.00	254.00	11.57	0.00	1.00	254.50	11.90	0.00	1.00
255.00	12.18	0.00	1.00	255.50	12.73	0.00	1.00	256.00	12.70	0.00	1.00	256.50	13.16	0.00	1.00
257.00	13.23	0.00	1.00	257.50	13.77	0.00	1.00	258.00	14.29	0.00	1.00	258.50	14.55	0.00	1.00
259.00	14.14	0.00	1.00	259.50	14.57	0.00	1.00	260.00	14.70	0.00	1.00	260.50	14.64	0.00	1.00
261.00	15.13	0.00	1.00	261.50	14.96	0.00	1.00	262.00	15.03	0.00	1.00	262.50	15.17	0.00	1.00
263.00	15.08	0.00	1.00	263.50	14.96	0.00	1.00	264.00	14.98	0.00	1.00	264.50	14.81	0.00	1.00
265.00	14.57	0.00	1.00	265.50	14.52	0.00	1.00	266.00	14.28	0.00	1.00	266.50	14.04	0.00	1.00
267.00	13.89	0.00	1.00	267.50	13.63	0.00	1.00	268.00	13.26	0.00	1.00	268.50	12.64	0.00	1.00
269.00	12.62	0.00	1.00	269.50	12.30	0.00	1.00	270.00	12.34	0.00	1.00	270.50	11.82	0.00	1.00
271.00	11.69	0.00	1.00	271.50	11.56	0.00	1.00	272.00	11.27	0.00	1.00	272.50	11.10	0.00	1.00
273.00	10.98	0.00	1.00	273.50	11.50	0.00	1.00	274.00	11.13	0.00	1.00	274.50	11.35	0.00	1.00
275.00	11.16	.14	2.00	275.50	11.29	0.00	1.00	276.00	11.13	0.00	1.00	276.50	10.35	0.00	1.00
277.00	10.94	0.00	1.00	277.50	11.23	.18	2.00	278.00	11.12	0.00	1.00	278.50	11.63	0.00	1.00
279.00	11.81	0.00	1.00	279.50	12.42	0.00	1.00	280.00	12.82	.19	2.00	280.50	12.78	0.00	1.00
281.00	13.05	0.00	1.00	281.50	13.31	0.00	1.00	282.00	13.34	0.00	1.00	282.50	13.74	0.00	1.00
283.00	13.78	.03	2.00	283.50	14.18	0.00	1.00	284.00	13.97	0.00	1.00	284.50	13.73	0.00	1.00
285.00	13.28	0.00	1.00	285.50	14.06	.05	2.00	286.00	13.31	0.00	1.00	286.50	13.44	0.00	1.00
287.00	14.04	0.00	1.00	287.50	13.39	0.00	1.00	288.00	13.32	.41	2.00	288.50	13.53	0.00	1.00
289.00	13.18	0.00	1.00	289.50	13.08	0.00	1.00	290.00	13.10	0.00	1.00	290.50	12.71	.32	2.00
291.00	12.72	0.00	1.00	291.50	11.90	0.00	1.00	292.00	11.62	.37	2.00	292.50	11.60	0.00	1.00
293.00	11.26	.18	2.00	293.50	11.23	0.00	1.00	294.00	11.50	0.00	1.00	294.50	11.79	.13	2.00
295.00	12.06	0.00	1.00	295.50	12.05	.15	2.00	296.00	12.36	0.00	1.00	296.50	12.49	.24	2.00
297.00	12.44	0.00	1.00	297.50	12.47	0.00	1.00	298.00	13.23	.08	2.00	298.50	13.21	0.00	1.00
299.00	13.33	.10	2.00	299.50	13.18	0.00	1.00	300.00	13.54	.41	2.00	300.50	12.75	0.00	1.00
301.00	13.39	0.00	1.00	301.50	13.35	.18	2.00	302.00	13.16	0.00	1.00	302.50	13.23	.32	2.00

POLAR PLOT NUMBER 1 PLOTTED
END OF DATA TO BE PLOTTED

Figure C15 (Continued)



IGURE C16 EXAMPLE POLAR PLOT

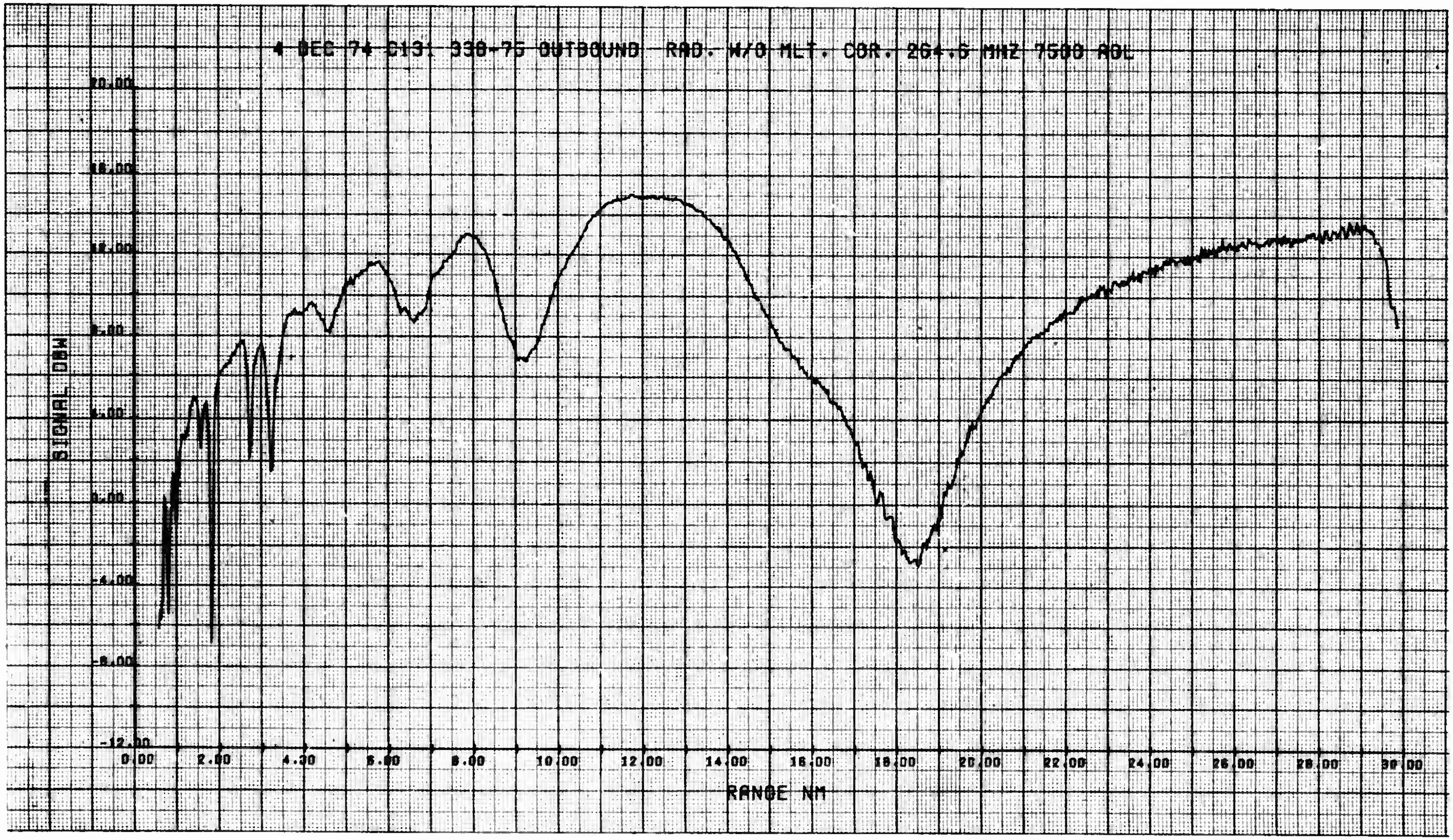
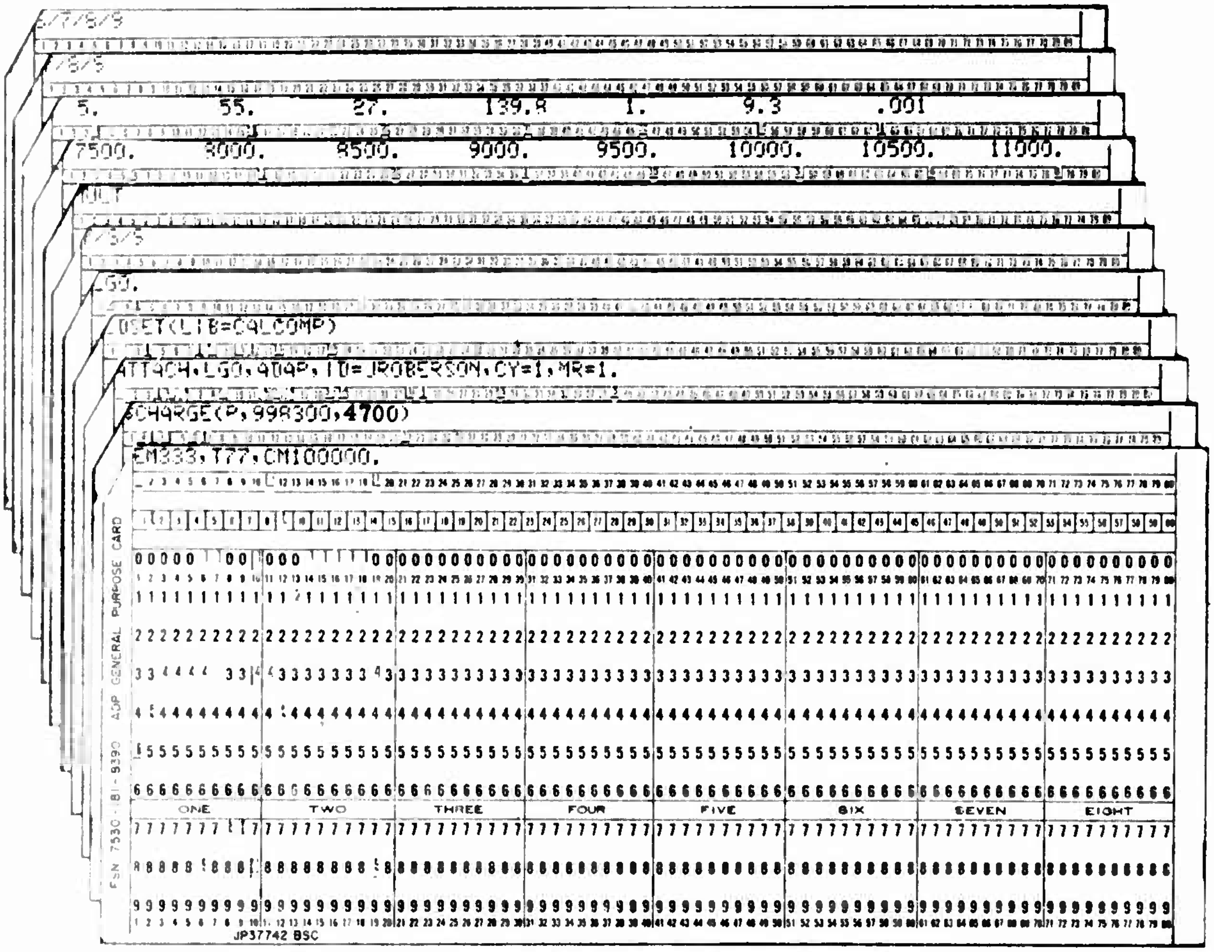


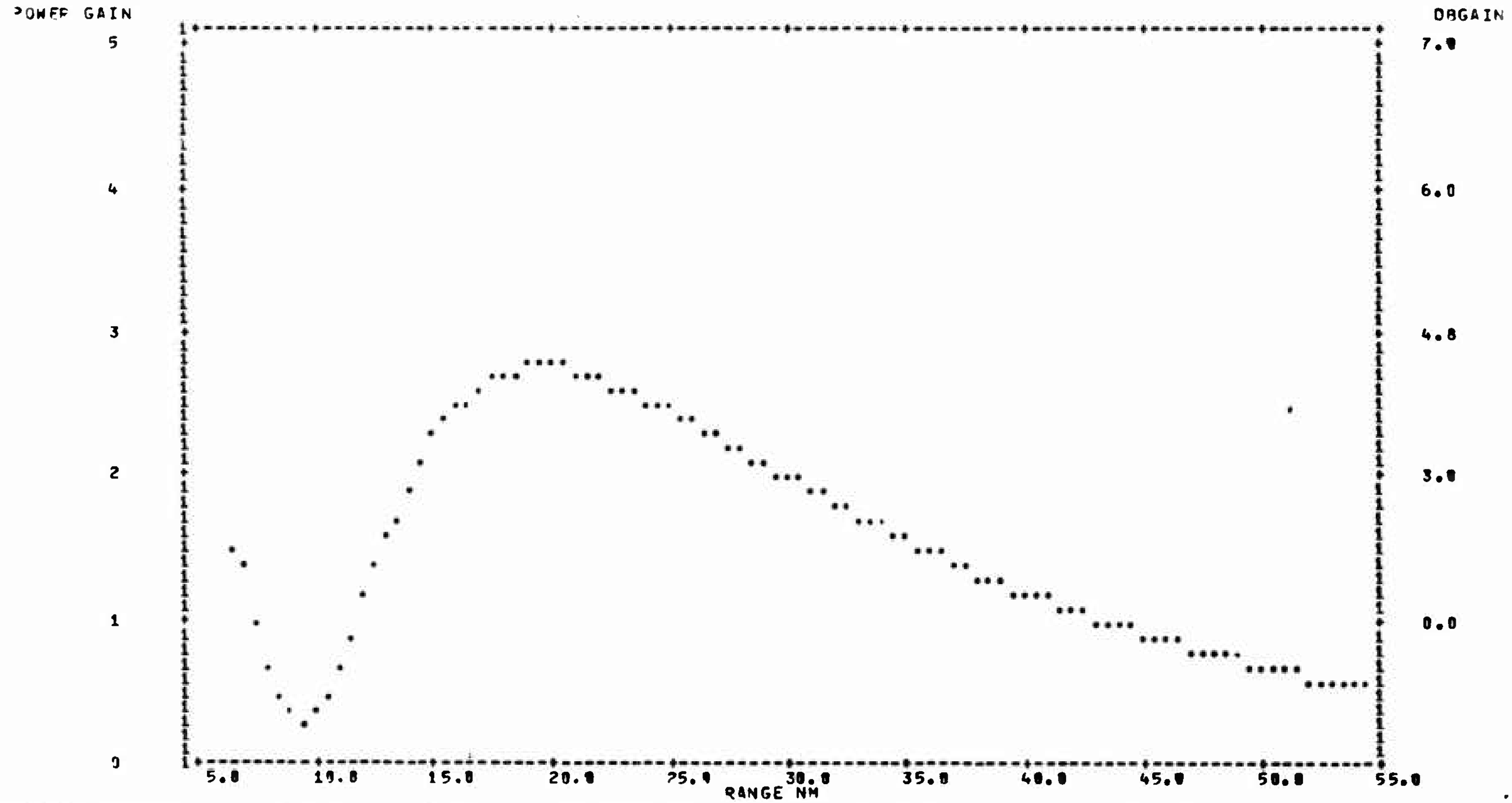
FIGURE C17 EXAMPLE RANGE PLOT



Note: Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer

Figure C18 Example MULT Deck

POWER GAIN PLOT AT ALTITUDE OF
7500.000 FT. AGL.



DISTANCE INTERVAL NM   ANTENNA HEIGHT FT.   FREQUENCY MHZ   POL(0=H, 1=V)   PERMITTIVITY   CONDUCTIVITY
5. TO   55.   27.0   139.80   1.00   9.30   .00100

CALCULATED INDEX OF REFRACTION SQUARED   DISTANCE FR. ANTENNA TO REFLECTION PT. NM. MINIMUM   MAXIMUM
9.3000   -.1288 J   .02   .26

Figure C19 Example MULT Listing

RANGE (NM)	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
GAIN (DB)	1.00	0.00	0.90	1.36	1.46	-.08	-1.54	-3.09	-4.28	-4.60
ELEV. ANG (DEG)	13.86	12.65	11.62	10.75	10.00	9.34	8.77	8.26	7.81	7.40
REF. DIST. (NM)	.02	.02	.02	.02	.03	.03	.03	.03	.03	.03
RANGE (NM)	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50
GAIN (DB)	-3.98	-2.87	-1.71	-.54	.67	1.36	1.94	2.42	2.82	3.15
ELEV. ANG (DEG)	7.04	6.70	6.40	6.12	5.87	5.64	5.42	5.22	5.04	4.86
REF. DIST. (NM)	.04	.04	.04	.04	.04	.05	.05	.05	.05	.05
RANGE (NM)	15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50
GAIN (DB)	3.54	3.75	3.92	4.05	4.15	4.29	4.33	4.37	4.40	4.41
ELEV. ANG (DEG)	4.70	4.55	4.41	4.28	4.15	4.03	3.92	3.82	3.72	3.62
REF. DIST. (NM)	.06	.06	.06	.06	.06	.07	.07	.07	.07	.07
RANGE (NM)	20.00	20.50	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50
GAIN (DB)	4.41	4.40	4.36	4.33	4.29	4.23	4.18	4.13	4.04	3.99
ELEV. ANG (DEG)	3.53	3.44	3.36	3.29	3.21	3.14	3.07	3.01	2.94	2.88
REF. DIST. (NM)	.07	.08	.08	.08	.08	.09	.09	.09	.09	.09
RANGE (NM)	25.00	25.50	26.00	26.50	27.00	27.50	28.00	28.50	29.00	29.50
GAIN (DB)	3.92	3.83	3.76	3.65	3.58	3.48	3.40	3.29	3.22	3.10
ELEV. ANG (DEG)	2.83	2.77	2.72	2.67	2.62	2.57	2.52	2.48	2.44	2.40
REF. DIST. (NM)	.09	.10	.10	.10	.10	.11	.11	.11	.11	.11
RANGE (NM)	30.00	30.50	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50
GAIN (DB)	2.99	2.91	2.80	2.69	2.60	2.49	2.37	2.26	2.18	2.07
ELEV. ANG (DEG)	2.36	2.32	2.28	2.24	2.21	2.17	2.14	2.11	2.08	2.05
REF. DIST. (NM)	.12	.12	.12	.12	.13	.13	.13	.13	.14	.14
RANGE (NM)	35.00	35.50	36.00	36.50	37.00	37.50	38.00	38.50	39.00	39.50
GAIN (DB)	1.95	1.84	1.73	1.62	1.51	1.40	1.29	1.18	1.07	.96
ELEV. ANG (DEG)	2.02	1.99	1.96	1.94	1.91	1.88	1.86	1.84	1.81	1.79
REF. DIST. (NM)	.14	.14	.15	.15	.15	.15	.16	.16	.16	.16
RANGE (NM)	40.00	40.50	41.00	41.50	42.00	42.50	43.00	43.50	44.00	44.50
GAIN (DB)	.86	.75	.65	.51	.40	.30	.17	.07	-.06	-.16
ELEV. ANG (DEG)	1.77	1.75	1.72	1.70	1.68	1.66	1.64	1.62	1.61	1.59
REF. DIST. (NM)	.17	.17	.17	.18	.18	.18	.18	.19	.19	.19
RANGE (NM)	45.00	45.50	46.00	46.50	47.00	47.50	48.00	48.50	49.00	49.50
GAIN (DB)	-.29	-.38	-.51	-.64	-.73	-.85	-.97	-1.09	-1.21	-1.32
ELEV. ANG (DEG)	1.57	1.55	1.54	1.52	1.50	1.49	1.47	1.46	1.44	1.43
REF. DIST. (NM)	.20	.20	.20	.21	.21	.21	.22	.22	.22	.23
RANGE (NM)	50.00	50.50	51.00	51.50	52.00	52.50	53.00	53.50	54.00	54.50
GAIN (DB)	-1.44	-1.55	-1.67	-1.78	-1.92	-2.02	-2.13	-2.26	-2.40	-2.50
ELEV. ANG (DEG)	1.41	1.40	1.39	1.37	1.36	1.35	1.33	1.32	1.31	1.30
REF. DIST. (NM)	.23	.23	.24	.24	.24	.25	.25	.26	.26	.26

Figure C19 (Continued)

Parameter Identification Card

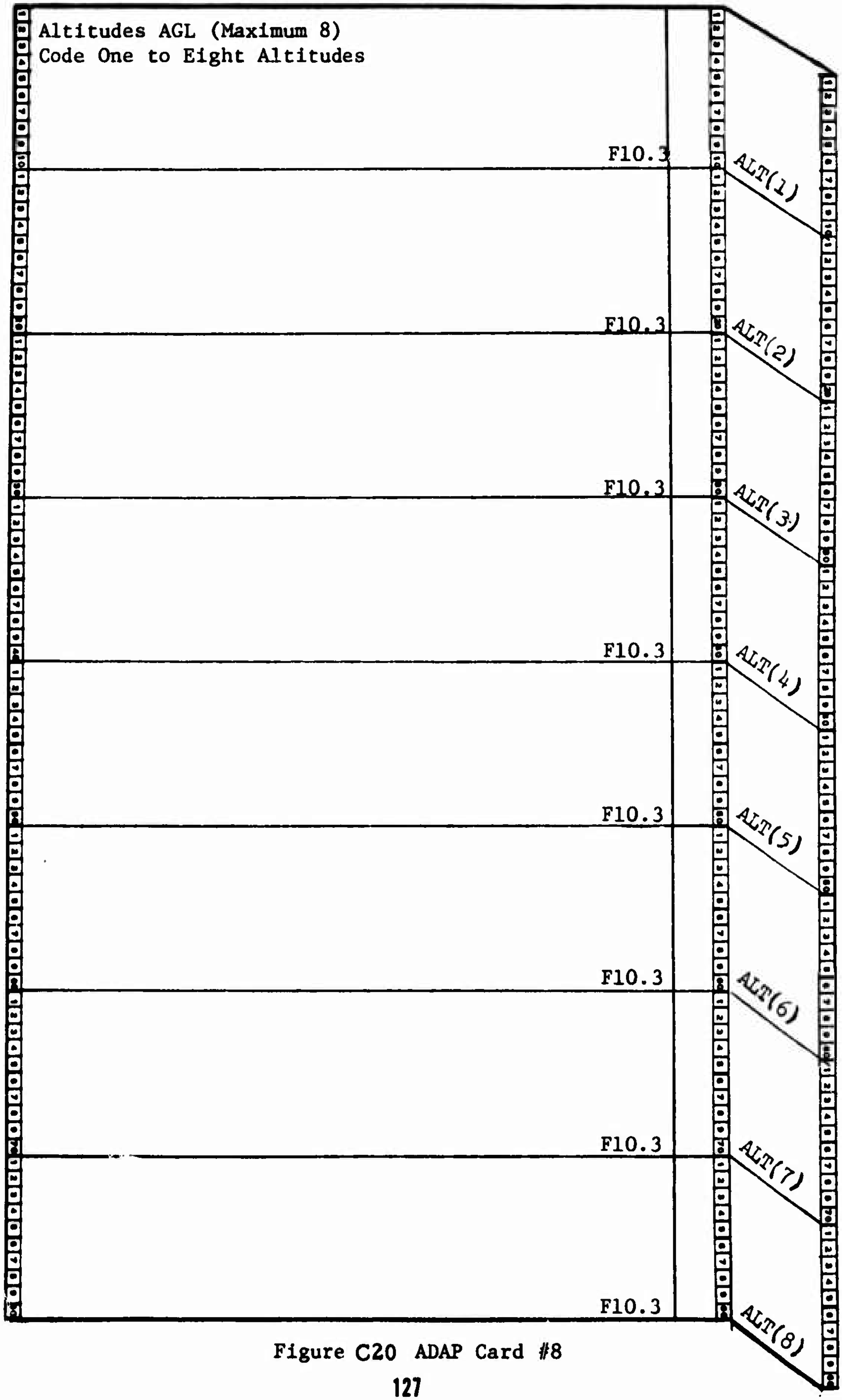


Figure C20 ADAP Card #8

Parameter Identification Card

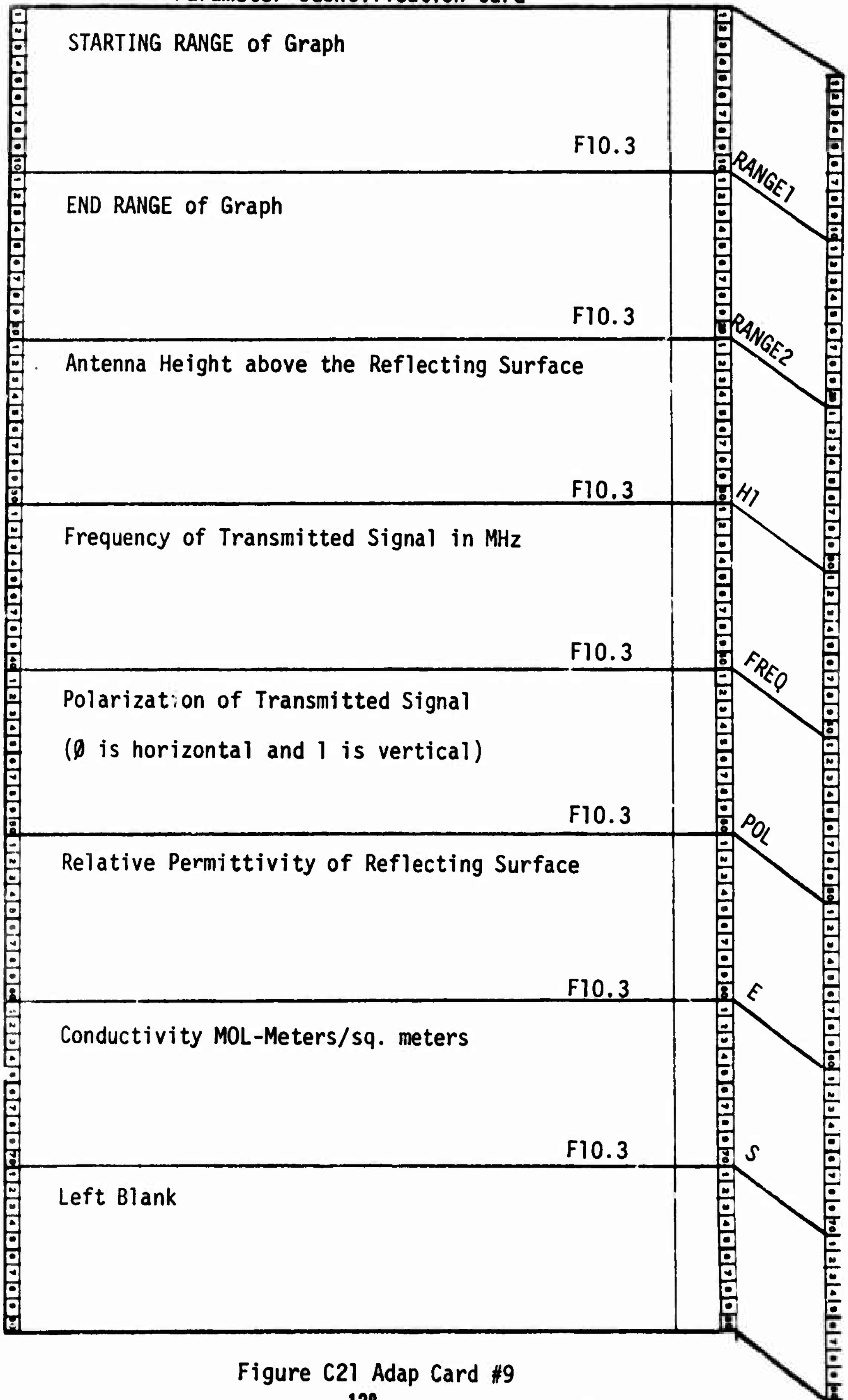


Figure C21 Adap Card #9

Parameter Identification Card

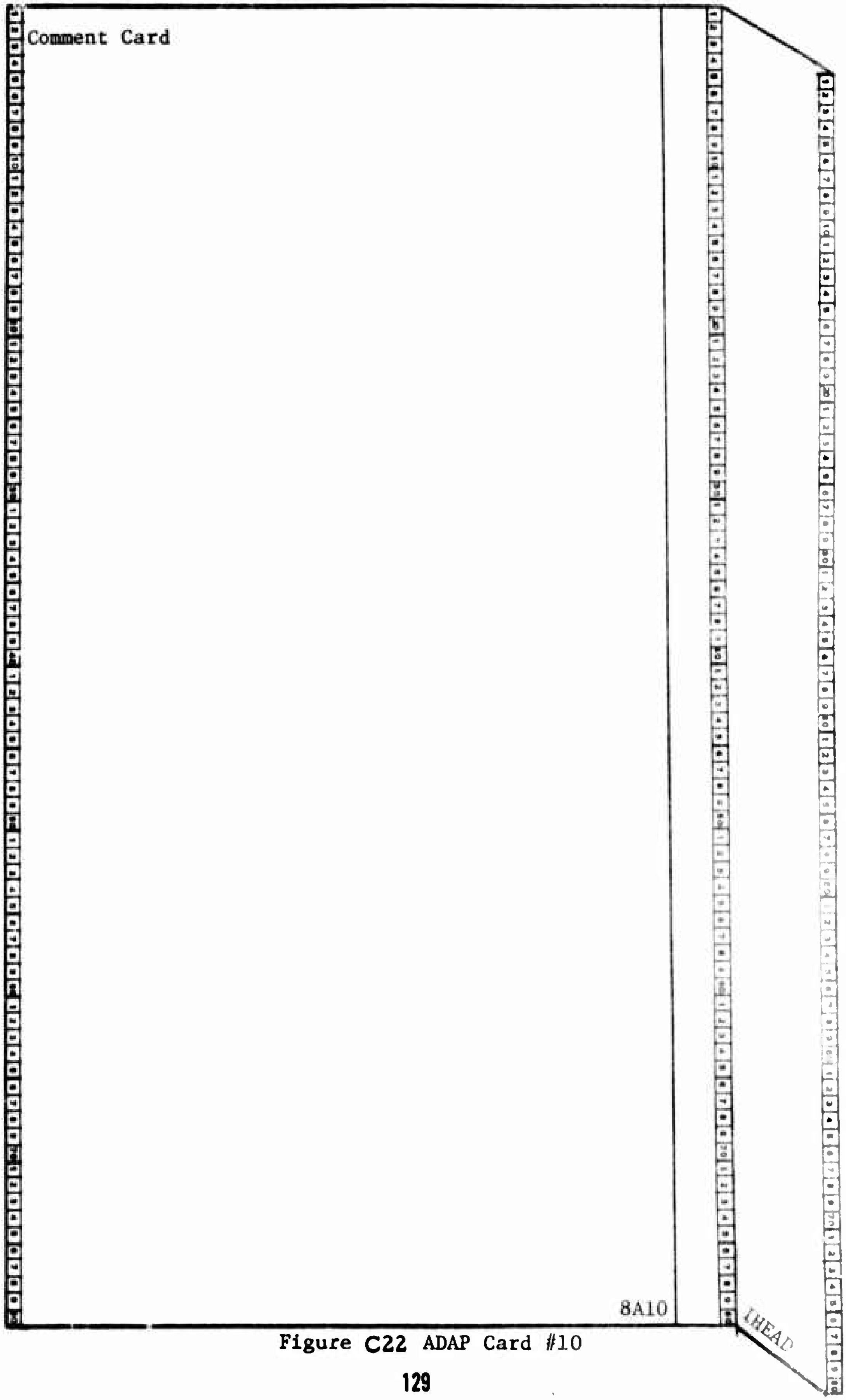
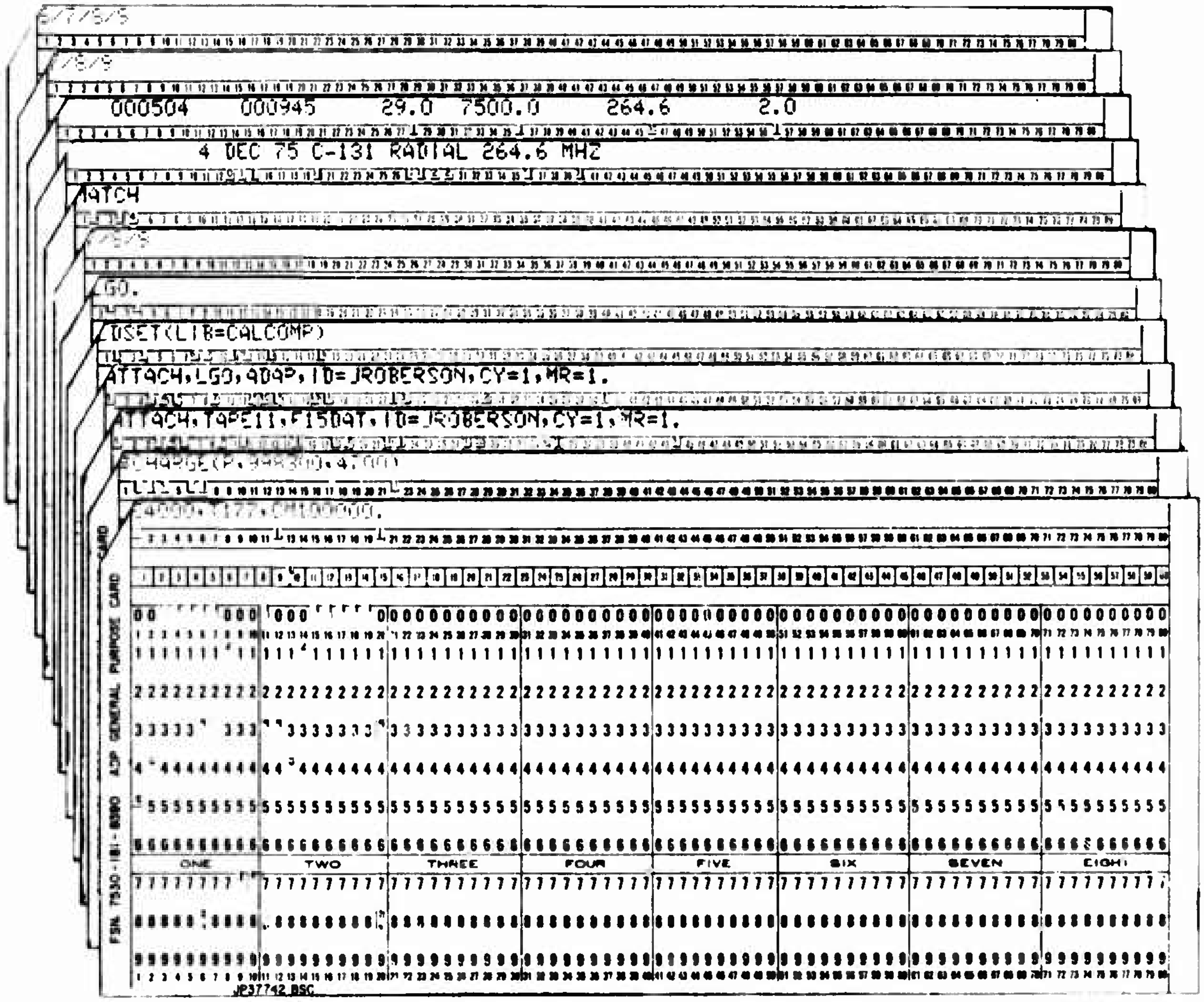


Figure C22 ADAP Card #10

Parameter Identification Card

Field		Format	Variable
Start Time	Hours	I2	ISTR(1)
	Minutes	I2	ISTR(2)
	Seconds	I2	ISTR(3)
Stop Time	Hours	I2	ISTP(1)
	Minutes	I2	ISTP(2)
	Seconds	I2	ISTP(3)
Height of Receiving Antenna in ft. above the Reflecting Surface		F10.2	HT
Height in ft. of the Aircraft Above the Reflecting Surface		F10.2	ACHT
Frequency of Transmitted Signal in MHz		F10.2	FREQ
Source Number of Data to be Matched (Must correspond to the No. written by the Antenna Radiation Pattern Measurement Program)		I10	ISR
Left Blank			

Figure C23 ADAP Card #11



Note: Exact Format of Cards Depends Upon the Version of SCOPE Being Used on the CDC 6500 Computer

Figure C24 Example MATCH Deck

```
                                    MULTIPATH MATCHING PROGRAM

              4 DEC 75 C-131 RADIAL 264.6 MHZ
START TIME =    0 HR   5 MIN   4 SEC      TOTAL SEC =      304.
STOP TIME  =    0 HR   9 MIN  45 SEC       TOTAL SEC =      585.
ANTENNA         HEIGHT =     29.000 AIRCRAFT ALTITUDE AGL =      7500. FREQUENCY     =    264.600 SOURCE NUMBER =   2

****************************************************************************************************
****************************************************************************************************

 BEST FIT WAS FOUND WITH PERMITTIVITY =         4.50 CONDUCTIVITY =        .001
   CALCULATED REFLECTIVITY =          4.50    -.870
 AVERAGE SIGNAL=       9.175   STANDARD DEVIATION =       1.312

****************************************************************************************************
****************************************************************************************************
```

Figure C25 Example MATCH Listing

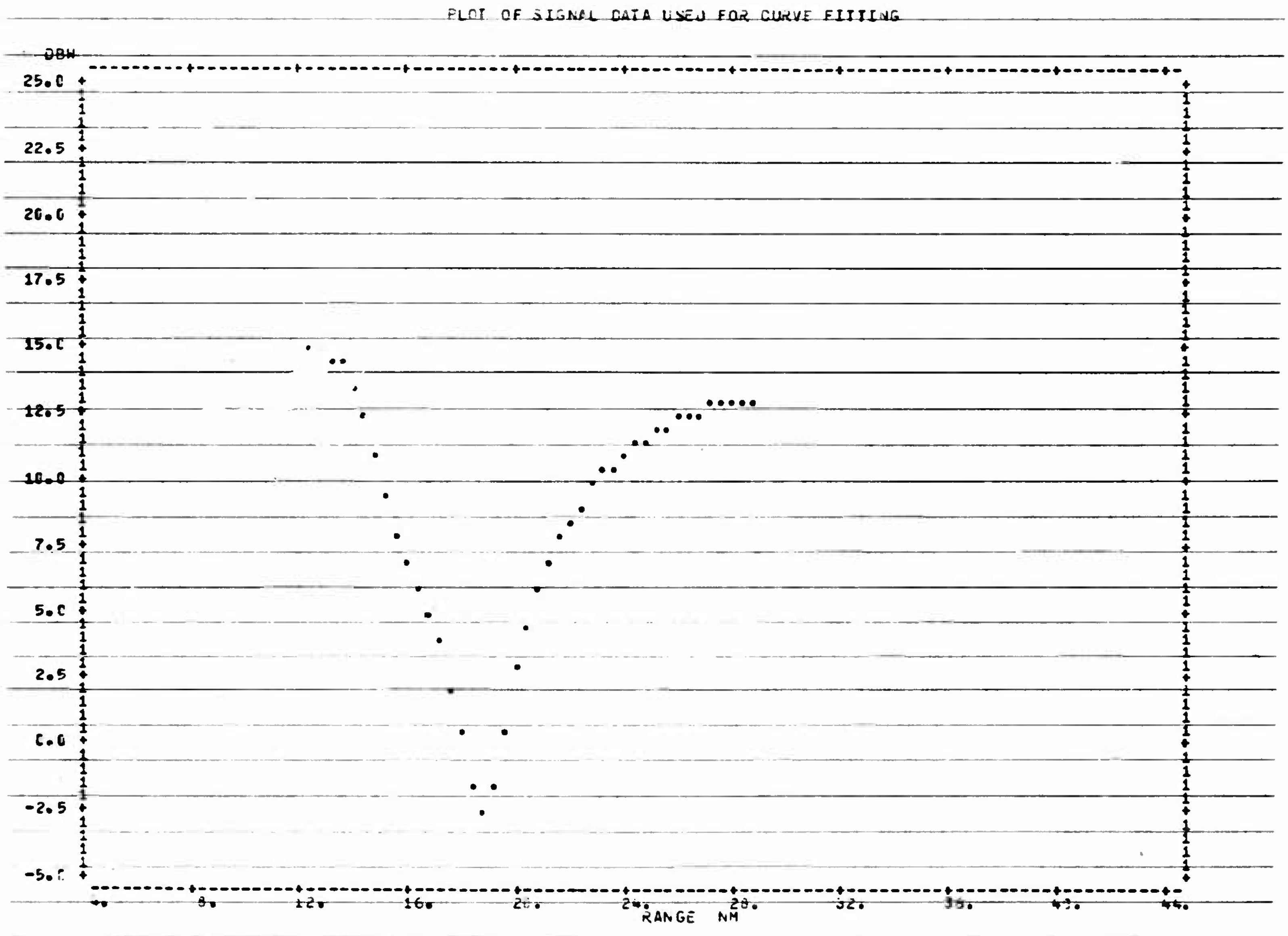


Figure C25 (Continued)

SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM
0.00	4.00	0.00	4.40	0.00	4.80	0.00	5.20	0.00	5.60
0.00	6.00	0.00	6.40	0.00	6.80	0.00	7.20	0.00	7.60
0.00	8.00	0.00	8.40	0.00	8.80	0.00	9.20	0.00	9.60
0.00	10.00	0.00	10.40	0.00	10.80	0.00	11.20	0.00	11.60
14.86	12.00	14.85	12.40	14.71	12.80	14.34	13.20	13.65	13.60
12.65	14.00	11.69	14.40	9.56	14.80	7.94	15.20	5.92	15.60
5.95	16.00	[illegible]	16.40	3.36	16.80	2.[illegible]4	17.20	.28	17.60
-1.50	18.00	-2.65	18.40	-1.47	18.80	.52	19.20	2.04	19.60
4.35	20.00	5.76	20.40	6.39	20.80	7.91	21.20	8.36	21.60
9.15	22.00	9.[illegible]	22.40	10.25	22.80	10.57	23.20	10.39	23.60
11.29	24.00	11.57	24.40	11.78	24.80	12.16	25.20	12.37	25.60
12.55	26.00	12.37	26.40	12.70	26.80	12.83	27.20	12.92	27.60
13.07	28.00	13.12	28.40	0.00	28.80	0.00	29.20	0.00	29.60
0.00	30.00	0.00	30.40	0.00	30.80	0.00	31.20	0.00	31.60
0.00	32.00	0.00	32.40	0.00	32.80	0.00	33.20	0.00	33.60
0.00	34.00	0.00	34.40	0.00	34.80	0.00	35.20	0.00	35.60
0.00	36.00	0.00	36.40	0.00	36.80	0.00	37.20	0.00	37.60
0.00	38.00	0.00	38.40	0.00	38.80	0.00	39.20	0.00	39.60
0.00	40.00	0.00	40.40	0.00	40.80	0.00	41.20	0.00	41.60
0.00	42.00	0.00	42.40	0.00	42.80	0.00	43.20	0.00	43.60
0.00	44.00								

Figure C25 (Continued)

PLOT OF BEST FITTING MULTIPATH EFFECT

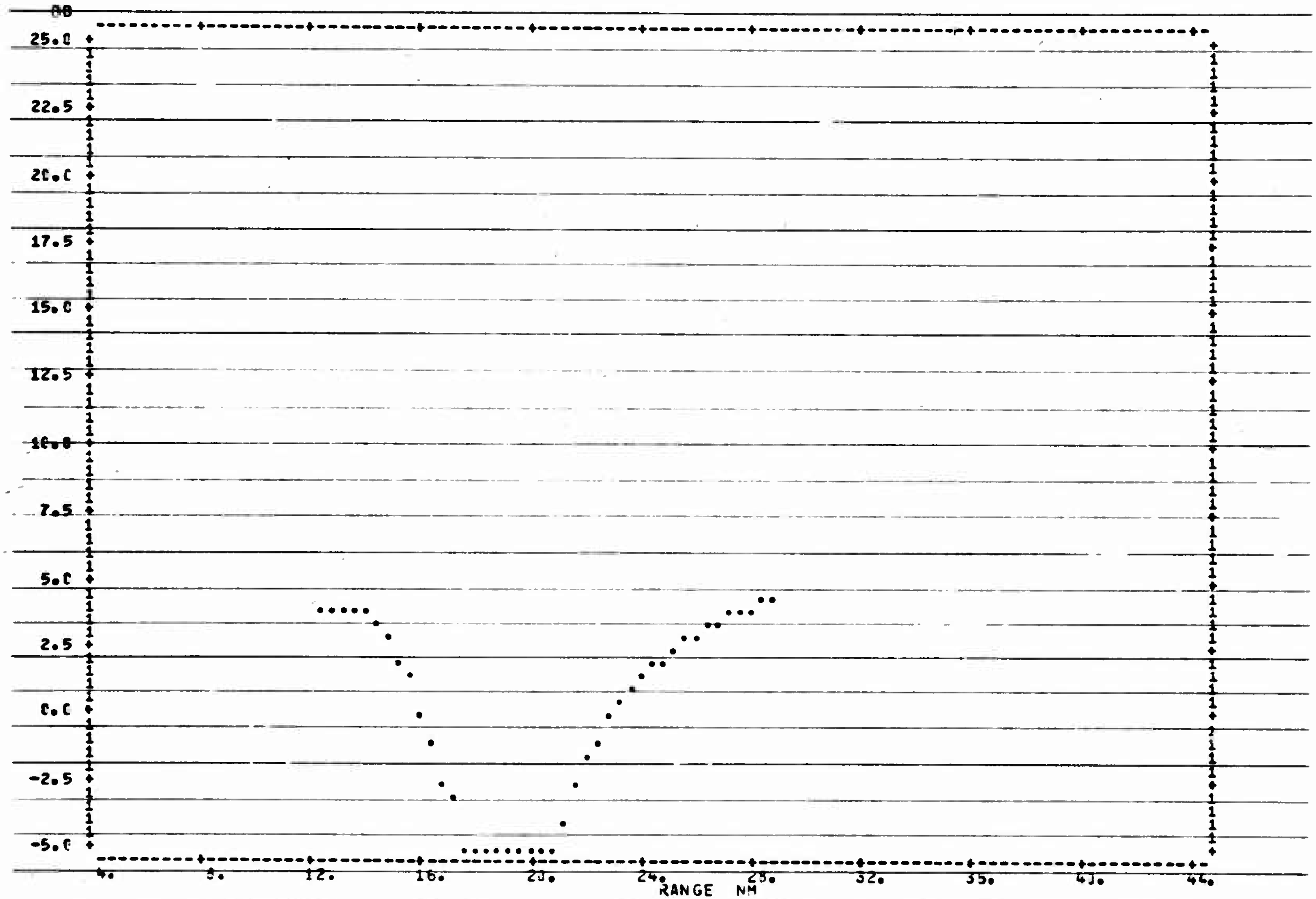


Figure C25 (Continued)

SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM
0.00	4.00	0.00	4.40	0.00	4.80	0.00	5.20	0.00	5.60
0.00	6.00	0.00	6.40	0.00	6.80	0.00	7.20	0.00	7.60
0.00	8.00	0.00	8.40	0.00	8.80	0.00	9.20	0.00	9.60
0.00	10.00	0.00	10.40	0.00	10.80	0.00	11.20	0.00	11.60
3.88	12.00	4.17	12.40	4.21	12.80	4.64	13.20	3.89	13.60
3.46	14.00	2.8[illegible]	14.40	2.14	14.80	1.26	15.20	.22	15.60
-1.00	16.00	-2.41	16.40	-3.20	16.80	-4.97	17.20	-7.00	17.60
-9.18	18.00	-13.98	18.40	-11.37	18.80	-10.14	19.20	-8.32	19.60
-6.57	20.00	-5.35	20.40	-3.77	20.80	-2.68	21.20	-1.74	21.60
-.94	22.00	-.24	22.40	.37	22.80	.90	23.20	1.38	23.60
1.86	24.00	2.16	24.40	2.52	24.80	2.82	25.20	3.18	25.60
3.34	26.00	3.56	26.40	3.77	26.80	4.33	27.20	4.19	27.60
4.33	28.00	4.46	28.40	0.00	28.80	0.00	29.20	0.00	29.60
0.00	30.00	0.00	30.40	0.00	30.80	0.00	31.20	0.00	31.60
0.00	32.00	0.00	32.40	0.00	32.80	0.00	33.20	0.00	33.60
0.00	34.00	0.00	34.40	0.00	34.80	0.00	35.20	0.00	35.60
0.00	36.00	0.00	36.40	0.00	36.80	0.00	37.20	0.00	37.60
0.00	38.00	0.00	38.40	0.00	38.80	0.00	39.20	0.00	39.60
0.00	40.00	0.00	40.40	0.00	40.80	0.00	41.20	0.00	41.60
0.00	42.00	0.00	42.40	0.00	42.80	0.00	43.20	0.00	43.60
0.00	44.00								

Figure C25 (Continued)

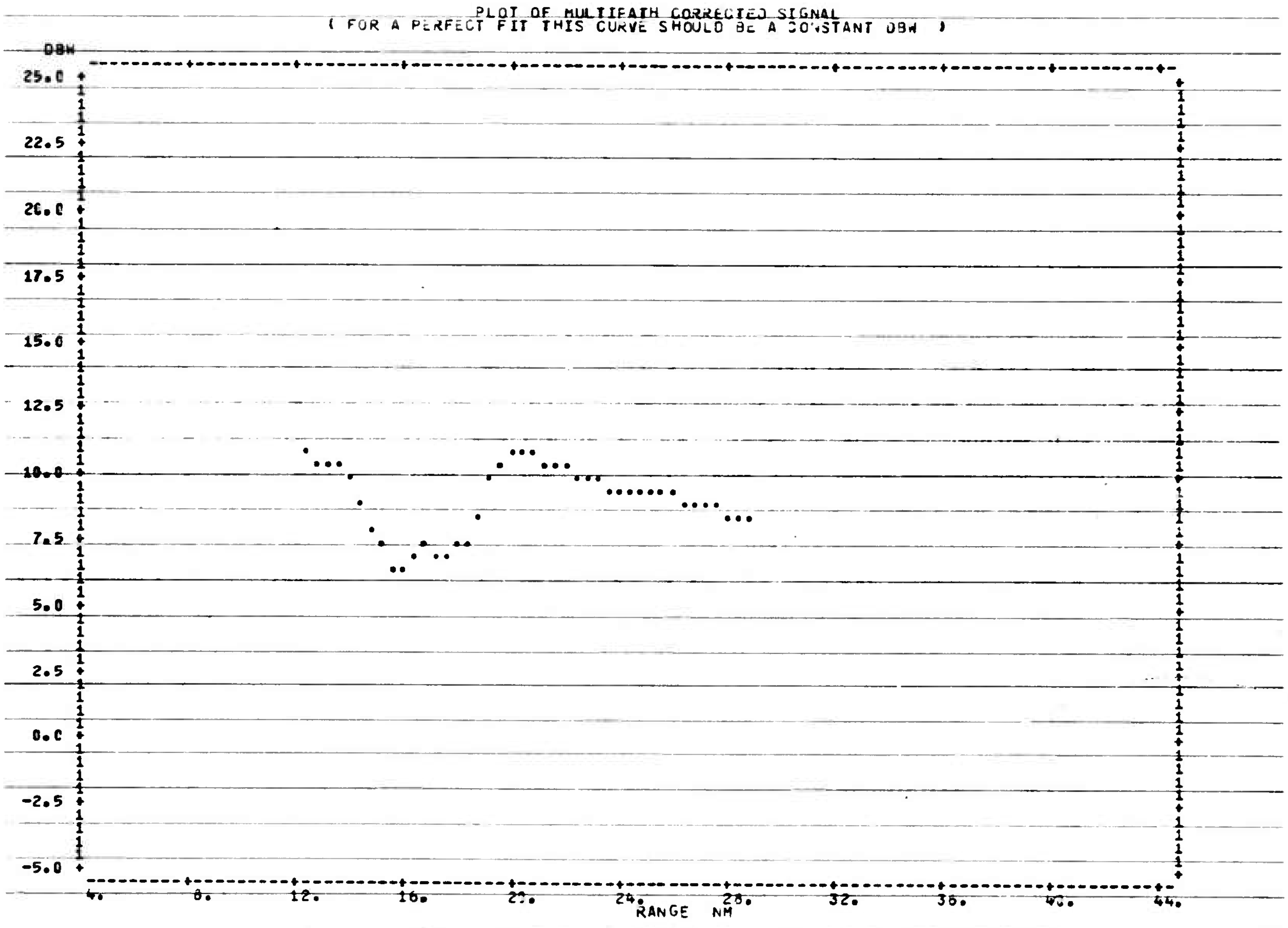


Figure C25 (Continued)

SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM	SIGNAL DB	RANGE NM
0.00	4.00	0.00	4.40	0.00	4.80	0.00	5.20	0.00	5.60
0.00	6.00	0.00	6.40	0.00	6.80	0.00	7.20	0.00	7.60
0.00	8.00	0.00	8.40	0.00	8.80	0.00	9.20	0.00	9.60
0.00	10.00	0.00	10.40	0.00	10.80	0.00	11.20	0.00	11.60
11.01	12.00	10.68	12.40	10.50	12.80	10.30	13.20	9.77	13.60
9.19	14.00	8.22	14.40	7.36	14.80	6.68	15.20	6.70	15.60
6.94	16.00	7.46	16.40	7.06	16.80	7.01	17.20	7.28	17.60
7.67	18.00	8.33	18.40	9.90	18.80	10.66	19.20	11.12	19.60
10.92	20.00	10.53	20.40	10.65	20.80	10.59	21.20	10.30	21.60
10.09	22.00	10.04	22.40	9.88	22.80	9.66	23.20	9.52	23.60
9.47	24.00	9.49	24.40	9.26	24.80	9.20	25.20	9.20	25.60
9.21	26.00	9.11	26.40	9.00	26.80	8.80	27.20	8.74	27.60
8.74	28.00	8.66	28.40	0.00	28.80	0.00	29.20	0.00	29.60
0.00	30.00	0.00	30.40	0.00	30.80	0.00	31.20	0.00	31.60
0.00	32.00	0.00	32.40	0.00	32.80	0.00	33.20	0.00	33.60
0.00	34.00	0.00	34.40	0.00	34.80	0.00	35.20	0.00	35.60
0.00	36.00	0.00	36.40	0.00	36.80	0.00	37.20	0.00	37.60
0.00	38.00	0.00	38.40	0.00	38.80	0.00	39.20	0.00	39.60
0.00	40.00	0.00	40.40	0.00	40.80	0.00	41.20	0.00	41.60
0.00	42.00	0.00	42.40	0.00	42.80	0.00	43.20	0.00	43.60
0.00	44.00								

Figure C25 (Continued)

APPENDIX D

ANTENNA PATTERN MEASUREMENT TEST

The antenna radiation pattern measurement technique developed for this report was the result of tests performed in the Fall of 1974 at Griffiss AFB, New York and Edwards AFB, California. These tests were designed to determine the ability of different flight techniques to accurately measure antenna pattern and to determine the antenna pattern measurement system to be established at the AFFTC.

This test was conducted in two phases using the Space and Missile Test Center's (SAMTEC) Radar Calibration C-131 (#803). The first phase was at Griffiss AFB using the Precision Antenna Measurement System (PAMS) and the second phase was at Edwards AFB using equipment at the Barrier Instrumentation Facility, building 275.

GRIFFISS AFB PHASE

The Griffiss AFB phase was conducted as a joint project between SAMTEC and AFFTC. The aircraft was scheduled by SAMTEC for a complete test of its antennas on the PAMS range. Therefore, to reduce cost AFFTC and SAMTEC combined both test requirements into one test program which was conducted in October 1974.

During the tests at PAMS, fifteen antennas were evaluated at eight different frequencies. This resulted in over 800 antenna pattern plots being produced. To excite the antennas, the aircraft was modified at Edwards AFB with racks and wiring for the installation of transmitters and the PAMS Airborne Monitoring System (AMS) for the recording of the aircraft altitude during the PAMS tests. The final installation of equipment was made at Griffiss AFB. The exciters used for the antennas being evaluated for SAMTEC were the airborne RF signal sources provided by PAMS. The exciter used for the antennas being evaluated for AFFTC were standard communication transmitters which were rated for continuous transmission. The 136.8 MHz CW signal was provided by a Wilcox 807A transmitter and the 225 MHz CW signal by an AN/PRC-66 portable transmitter.

The flight patterns flown at Griffiss consisted of: (1) radials, (2) parallel flybys, (3) cloverleaf, (4) orbits, and (5) polygon. Due to difficulties with the AMS, data on the orbit and polygon flights were lost. The data on 139.8 MHz and 225 MHz were collected using a circular polarized receiving antenna even though the transmitted signals were vertically polarized. This enabled data to be collected on nearly all the flights at Griffiss AFB, since the ground antenna was being used as circular polarization on all flights for SAMTEC. This caused all the plots of the 139.8 MHz and 225 MHz data to be 3.01 db low.

A total of six parallel flyby patterns were flown, one radial flight, one orbit flight and one cloverleaf flight with data collected on 139.8 MHz and 225 MHz. The flight patterns flown on the parallel flyby, cloverleaf, and radial patterns are shown in this report in figures D1 through D3.

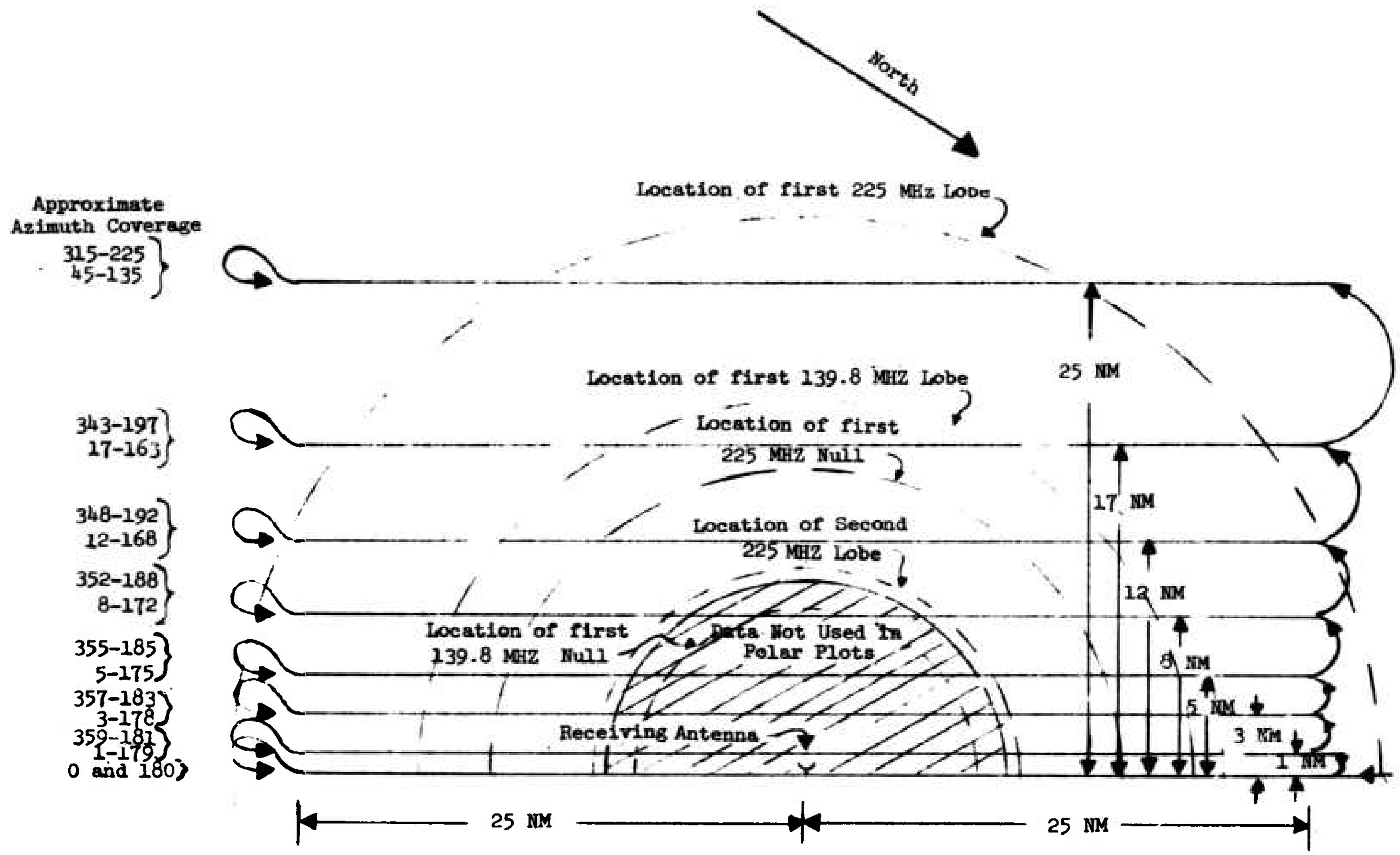


Figure D1 Parallel Flyby Flight Pattern Griffiss AFB

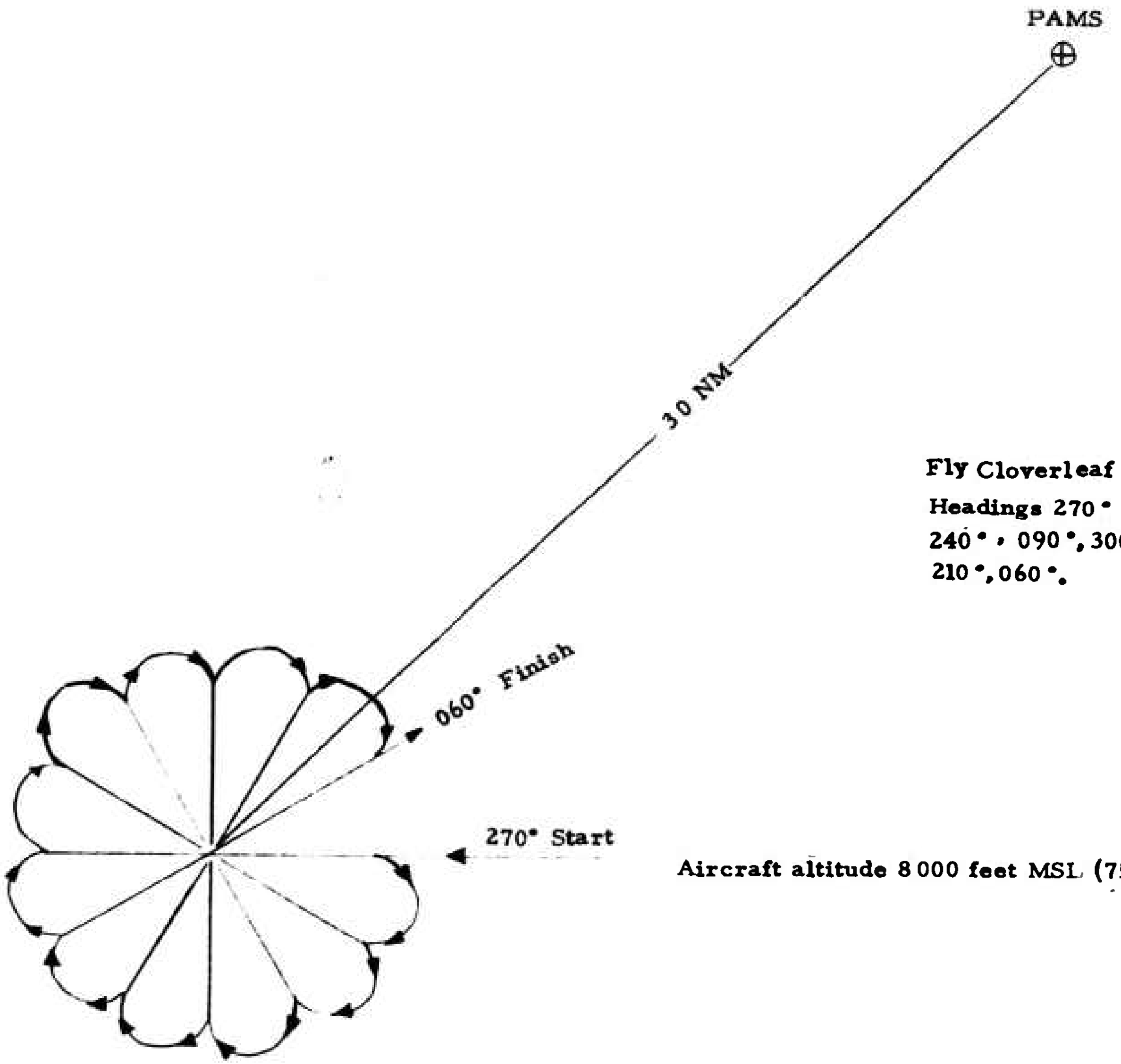


Figure D2 Cloverleaf Pattern Griffiss AFB

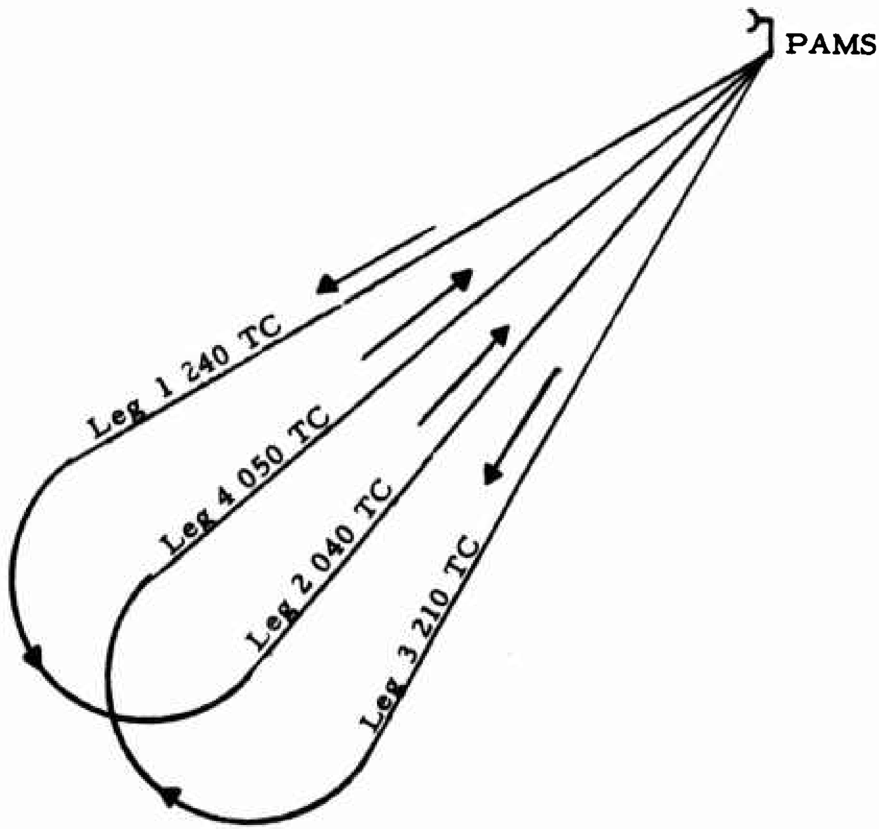


Figure D3 Radial Flight Paths Flown Griffiss AFB

The flights flown on the PAMS range for the SAMTEC and AFFTC tests required 50 hours of flying time which were flown, for the most part, from 0030 to 0830 hours. The flights at night were required to avoid interference of the UHF signal from local TV stations.

EDWARDS AFB PHASE

The second phase of the tests conducted at Edwards AFB was designed to determine the optimal technique to be used at the AFFTC and the equipment required for an antenna measurement system at Edwards AFB. As such, the same type of patterns were flown at Edwards as were flown on the PAMS range except modified parallel flybys were flown instead of parallel flybys (figures D4 and D5).

The tests were flown in December 1974 using the C-131 #803 with the Wilcox 801A VHF transmitter on 139.8 MHz and the AN/PRC-66 UHF transmitter on 264.6 MHz. The UHF signal was not the same frequency as the Griffiss AFB tests because the 225 MHz frequency was not among the AFFTC assigned frequencies. Therefore, slight differences are to be expected between the UHF antenna patterns of the PAMS and AFFTC tests.

The equipment available at the Barrier Test Facility located at South Base was used to record the signal strength data during the tests. The instrumentation system provided the basic equipment required to record the data and the IRIG "B" time required for time correlation with radar position data. The equipment indicated in the lower right section of figure D6 was available at the Barrier Facility and was used for the tests. The facility provided a 14 track Ampex FR 1600 instrumentation tape recorder which was used to record the data and IRIG "B" time code as received from the base timing system. The VHF time code receiver and demultiplexer provided time data which was recorded on tracks 11 and 12 of the FR 1600 tape recorder. The signal strength data was recorded on track 2 of the tape recorder using an IRIG channel 10 and an IRIG channel 13 voltage controlled oscillator (VCO). The automatic gain control (AGC) voltage of the Stoddard Model NM-30A VHF receiver was filtered with a lowpass filter to remove modulation components from the AGC voltage. This filter was not necessary with the TR-104 telemetry receiver used for the UHF signal receiver.

For the purpose of measuring received signal strength, the Barrier Instrumentation System was supplemented with additional equipment. An omnidirectional VHF and UHF antenna system was installed at an elevation of 27 feet above ground level. The antennas were connected to the receivers by approximately 45 feet of RF-213 coaxial cable. The signal loss was measured and recorded for each cable at the test frequencies of 139.8 MHz and 264.6 MHz.

The UHF signal was received by an Astro Communication Laboratory Type TR-104 Telemetry Receiver. The AGC voltage ranged from 0 volts at -110 dbm signal to approximately -5 volts at -40 dbm signal. This voltage was used as the input to the model VC-50 VCO operating at IRIG channel 13. The VCO was adjusted so that -110 dbm signal was approximately 90 percent of upper band edge and -40 dbm signal was approximately 10 percent of upper band edge.

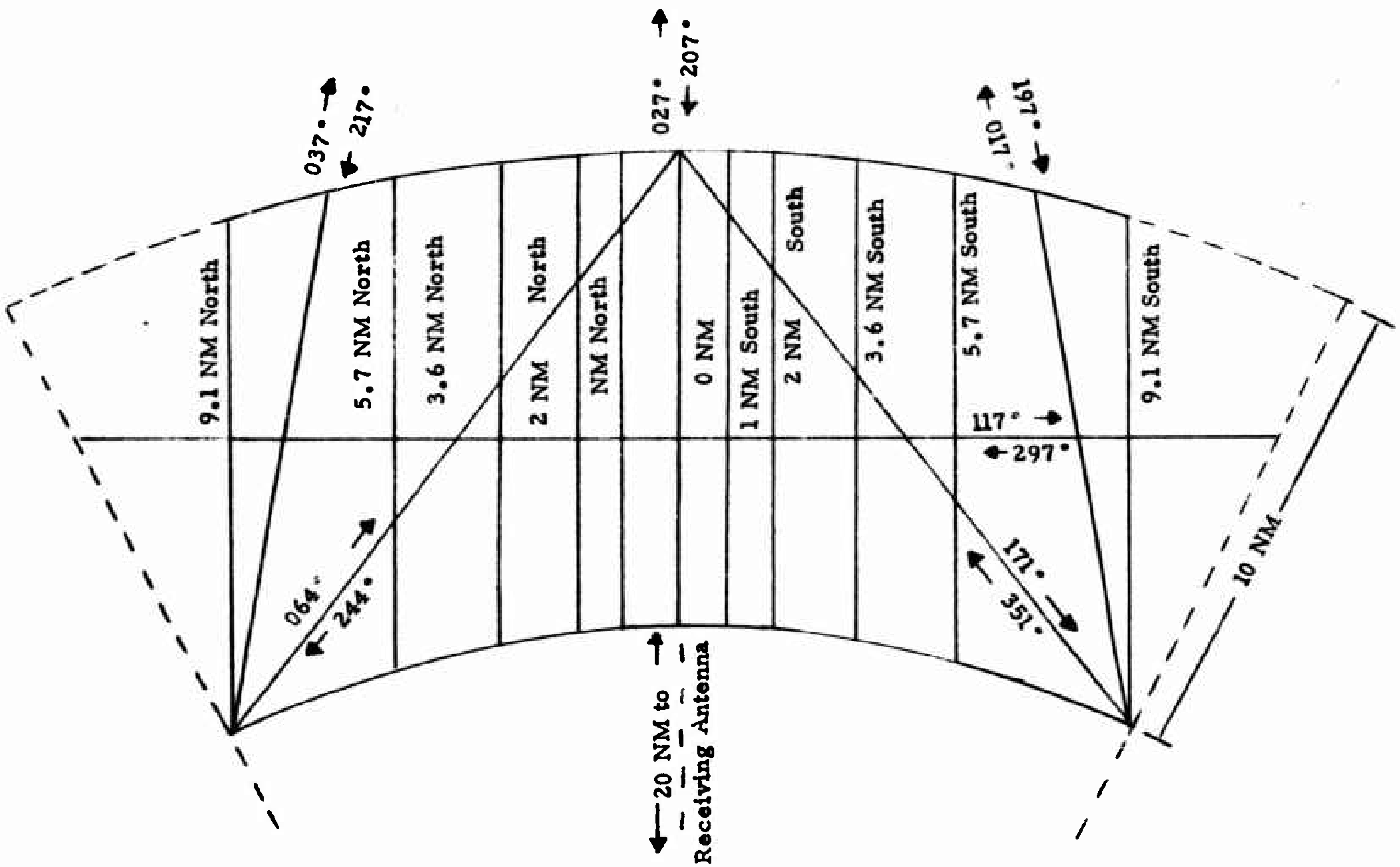


Figure D4 Modified Parallel Flyby Flight Pattern Edwards AFB Test

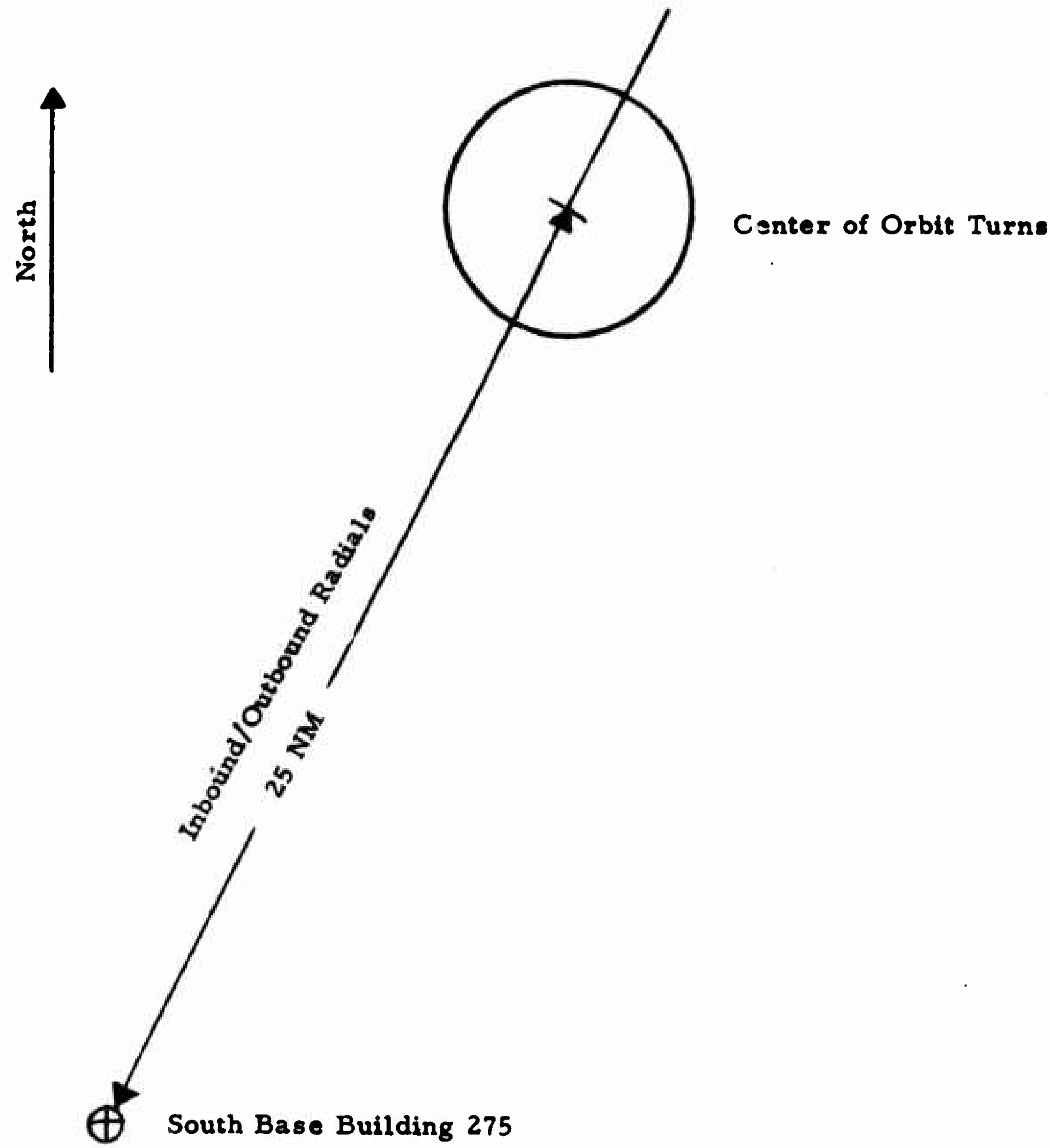


Figure D5 Radials Flown Edwards AFB

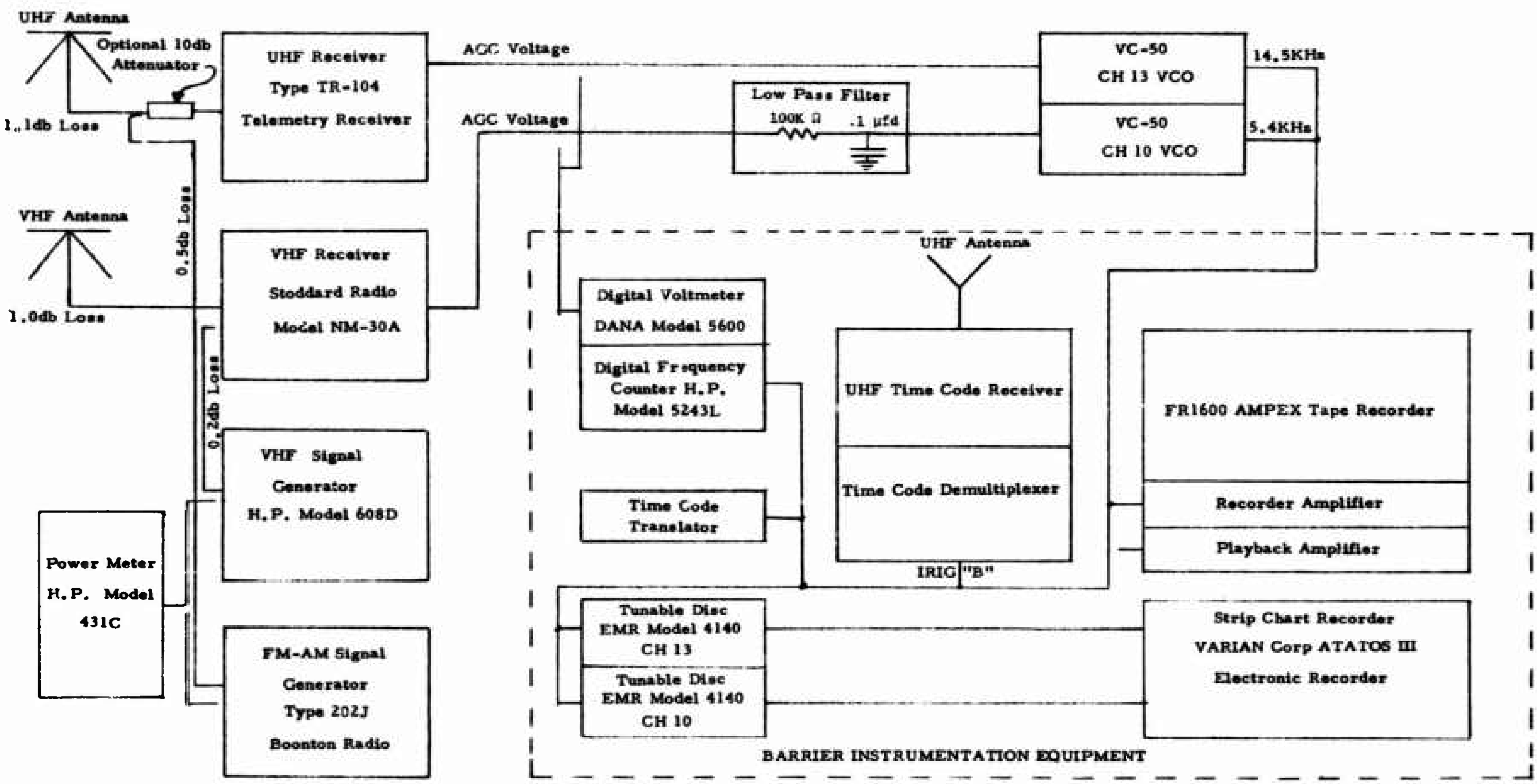


FIGURE D6 EDWARDS AFB TEST EQUIPMENT SETUP

A Stoddard Radio Field Intensity Meter was used to receive the VHF signals. The AGC voltage from this receiver was used as an input to a VC-50 VCO operating on IRIG channel 10. It was similarly adjusted so that -110 dbm signal was near upper band edge and a -40 dbm signal drove the VCO toward lower band edge. The two VCO outputs were mixed and both were recorded on track 2 of the tape recorder.

The signal loss from the antenna to receiver input was measured for each coaxial line at the test frequencies. This was accomplished by first measuring the output of the signal generator with the power meter directly at its output terminal. The feed line was then inserted between the signal generator and the power meter and the difference in power was noted. The signal loss for the coaxial lines used between the signal generator and the receivers were similarly measured at the test frequencies.

Prior to the start and after the completion of each flight, a series of calibration points were recorded on the FM tape. The signal generator provided the calibration signals to the receiver terminals in 5 dbm increments. This produced signal calibrations from -40 dbm to -90 dbm for the VHF receiver and -60 dbm to -110 dbm for the UHF receiver. The IRIG "B" time and signal strength were recorded for each calibration point for use by the Antenna Radiation Pattern Measurement Program to calibrate the recorded signal strength in dbm.

DATA ANALYSIS

Data collected during both phases of this test program were used for analysis of the multipath effects and flight techniques. Through the use of radial flight data, the ability to eliminate multipath radiation was evaluated and through the use of polar plots of the antenna patterns, flight techniques were reviewed for accuracy and repeatability of data.

Radial Flight Data:

The radial flights were designed to map the multipath radiation effects at both test facilities and to demonstrate the ability to eliminate the multipath effect through computer prediction. The Edwards AFB radials were plotted as signal (dbw) versus range and the Griffiss AFB radials were plotted as signal and range versus time. Since the receiving antenna at PAMS was receiving the vertically polarized transmitted signal as circular polarized, both left and right circular polarizations are plotted. Both polarizations should produce similar data, but transmission path effects cause differences to exist.

The Griffiss AFB radials show that a multipath lobing structure exists for the 139.8 MHz and 225 MHz data (figures D7 through D10). The lobes are large enough to produce significant effects on the polar plots and are especially significant between -10 and -90 degree depression angles, where the aircraft was within 10 NM of the receiving antenna.

The radials also show that multipath radiation is being received by the six foot dish antenna on 1435 MHz (figures D11 and D12). At 27 NM and 35 NM large cancellations occur but data at less than 25 NM does not show any multipath effect. This is due to the beam width of the six foot antenna being sufficiently narrow to eliminate the multipath radiation at the higher antenna elevation angles.

The Edwards radial data (figures D13 through D16) show the multipath lobing structure which existed during the Edwards AFB tests. The lobing structure was close to that which was expected. Since all orbits and modified parallel flybys were flown from 20 NM to 30 NM, only the 264.6 MHz data would be distorted due to the large null which exists between 15 NM and 24 NM.

The ability to eliminate the multipath signals by computer predictions is shown in figures D17 through D20. The areas of concern are from 20 NM to 30 NM where the orbit and modified flyby flights were flown. In this range all the radials are reduced to within ± 1 dB. Large errors exist up to 16 NM in the 264.6 MHz radial, corrected for multipath radiation (figures D19 and D20), due to approximations used in multipath predictions (appendix E). (R1)[1]

Additional radials were flown at Edwards AFB to determine if the TM site, building 5780, could be used to measure aircraft antenna radiation patterns in the VHF/UHF range. The data collected showed the effects of multipath radiation, with an omnidirectional receiving antenna, are too severe and unpredictable to use this site for VHF/UHF antenna pattern measurement. This is probably due to the height of the receiving antenna above the reflecting surface producing a large number of lobes and the changing terrain of the reflecting surface modifying the lobing structure.

Polar Plot Data (Griffiss AFB Test):

The polar plot data from the Griffiss AFB test (figures D21 through D27) was collected with the parallel flyby flight pattern (figure D1) and a cloverleaf (figure D2). Since multipath radiation was being received during these tests, the effect the reflected signal has on the recorded data must be considered when analyzing the antenna patterns.

The data, used in the 0 to -7 degree depression angle polar plots of the Griffiss AFB test, consists of all data collected during the parallel flyby flight pattern except the data when the aircraft was within 10 NM of the PAMS site.

The data used in creating the 0 to -7 degree depression angle polar plots, from the parallel flyby flight pattern, was collected from 10 NM to 35 NM from the receiving antenna. Data from all legs of the flight pattern are the averaged for each 0.5 degree in azimuth angle. Since most azimuth angles are covered in more than one leg, data are being averaged from different legs of the flight path.

The resulting effect of averaging data on different legs, in the presences of multipath radiation, will depend on the lobing structure of the signal. For the 139.8 MHz data, one lobe and one null was included for the data collected from 20 to 160 and 200 to 340 degrees

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[1] Numerals preceded by an R within parentheses at the end of a paragraph correspond to the recommendation numbers tabulated in the Conclusions and Recommendations section of this report.

azimuth angle around the aircraft. This has resulted in reducing the multipath effect in these azimuth angles.

For the azimuth angles around the nose and tail of the aircraft the data being used come from the 0, 1, and 3 NM legs. Since these are essentially radial legs, the lobing effect can be seen in the polar plots (figures D21, D22, D25, and D26).

As the frequency is increased more lobes will be present in the data. This has the effect of increasing the jagged appearance of the data over the nose and tail of the aircraft and possibly creating fictitious holes in the antenna pattern between 30 to 160 and 210 and 330 degrees.

Polar Plot Data (Edwards AFB Test):

The polar plot data from the Edwards AFB test was collected using orbits, cloverleaf, and a modified parallel flyby flight pattern (figure D4). All data was collected from 20 NM to 30 NM from the receiving antenna and in the presence of multipath radiation.

The effect of multipath radiation on the antenna patterns can easily be seen in figures D46 through D49. Since the orbit turns were conducted from 20 NM to 30 NM, the aircraft entered the first null of the 264.6 MHz signal. This resulted in the apparent depression of the antenna pattern on one side of the aircraft. For the banked turn the depression was not so pronounced due to the small turn radius keeping the aircraft from entering the deep portion of the null.

Through the use of the multipath correction option of the Antenna Radiation Pattern Measurement Program (ARPMP appendix B), the multipath effect was effectively eliminated (figures D58 through D64).

A comparison of skidding turns and polygon turns of the 139.8 MHz antenna patterns, corrected for multipath radiation (figures D37 through D45), shows that the general shape of the patterns are the same. Since there are numerous factors which can affect the received signal, an exact comparison of the antenna patterns cannot be expected. The primary concern for comparing the antenna patterns is the location and magnitude of losses in effective radiation power (ERP). Comparing the polar plots for these items indicates the skidding turns, polygon, and modified parallel flyby produce essentially equivalent antenna patterns. Due to savings in flight time and high quality of data, the skidding turn flight technique was judged the best technique. (R2)

A comparison of data between the two phases of the test must be conducted with the 139.8 MHz data, since this was the only data collected on the same frequency. Comparing the general shape of the antenna patterns shows the gains and losses are basically in the same location.

The major difference between the Griffiss AFB data and the Edwards AFB data is the magnitude of holes in the antenna patterns. The Griffiss data has holes of approximately twice the magnitude of the Edwards data. The reason for the difference has not been resolved at this time.

The equipment used during the Edwards phase of this test (figure D6) has produced repeatable results. With the addition of airborne transmitters, which are capable of transmitting multiple signals on antennas simultaneously, the equipment can provide an inexpensive permanent antenna radiation pattern measurement facility. (R3)

CONCLUSIONS AND RECOMMENDATIONS

Orbit turns have shown to be an effective flight technique to produce continuous coverage of an aircraft antenna radiation pattern. Through the use of the multipath prediction option of the Antenna Radiation Pattern Measurement Program (ARPMP), the effects of multipath radiation can be effectively eliminated.

1. To effectively eliminate multipath radiation effects in the VHF/UHF range, the multipath option of ARPMP should be used (page 148).

2. Orbit turns should be used when measuring aircraft antenna radiation patterns (page 149).

The antenna pattern measurement facility to be developed at AFFTC should be patterned after the equipment used in this test. This facility can produce accurate, repeatable results with equipment readily available on base. With the addition of airborne transmitters to excite two antennas with three signals each, aircraft antenna radiation patterns can be accurately, economically measured.

3. An antenna radiation patterns measurement facility should be installed at Edwards AFB patterned after the system used in this test (page 150).

FIGURE D7 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

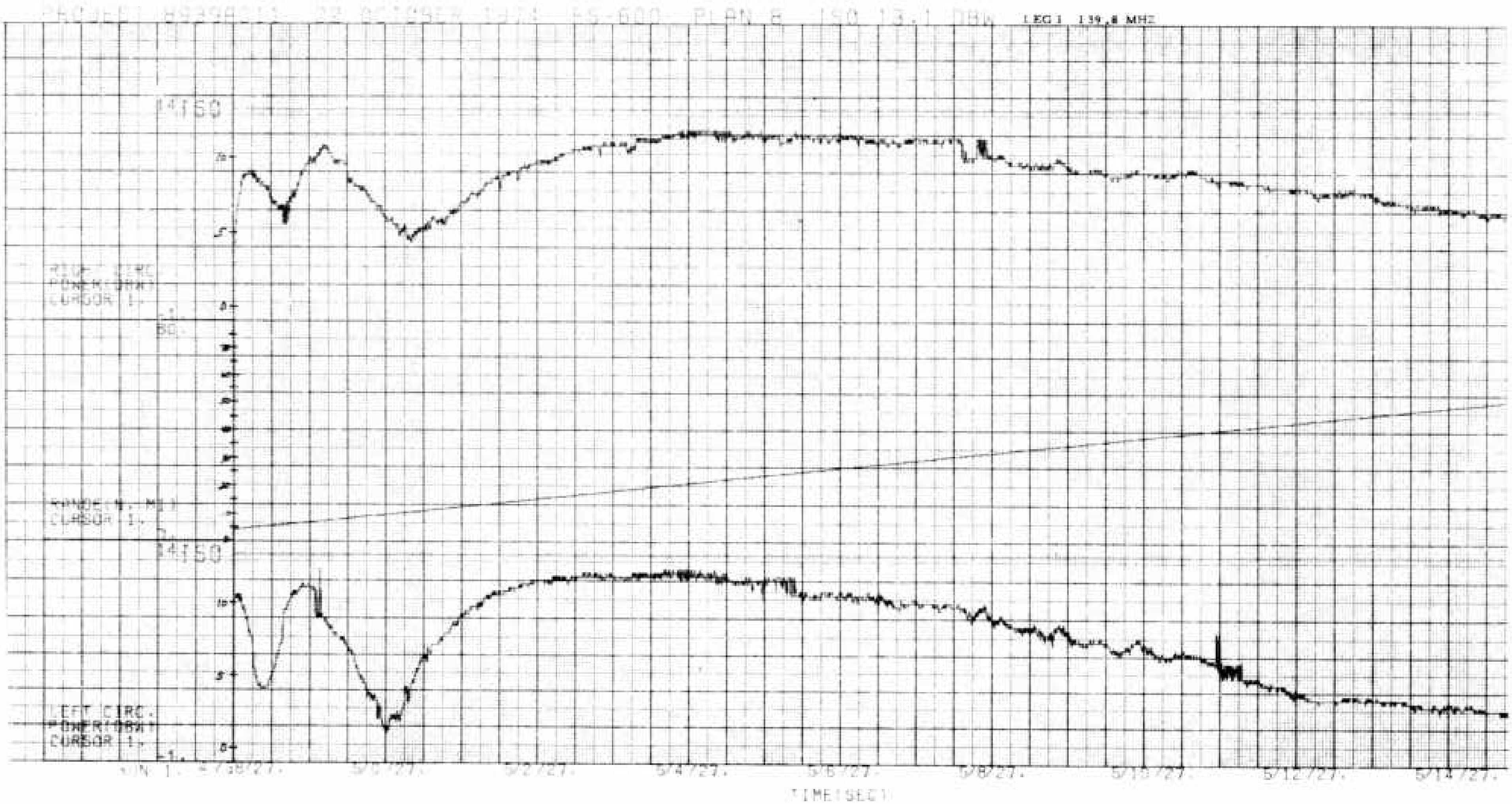

FIGURE D8 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

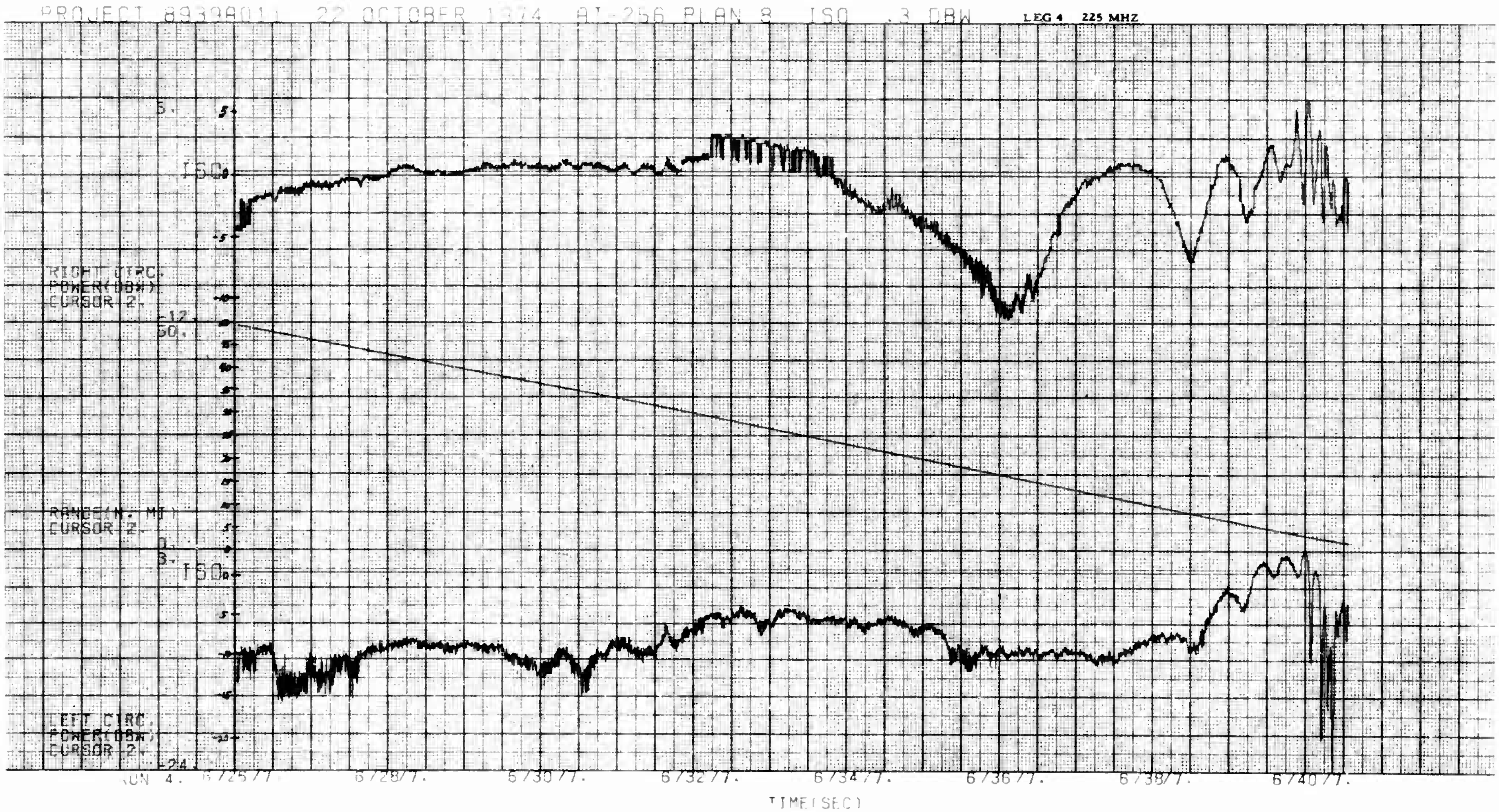

FIGURE 09 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

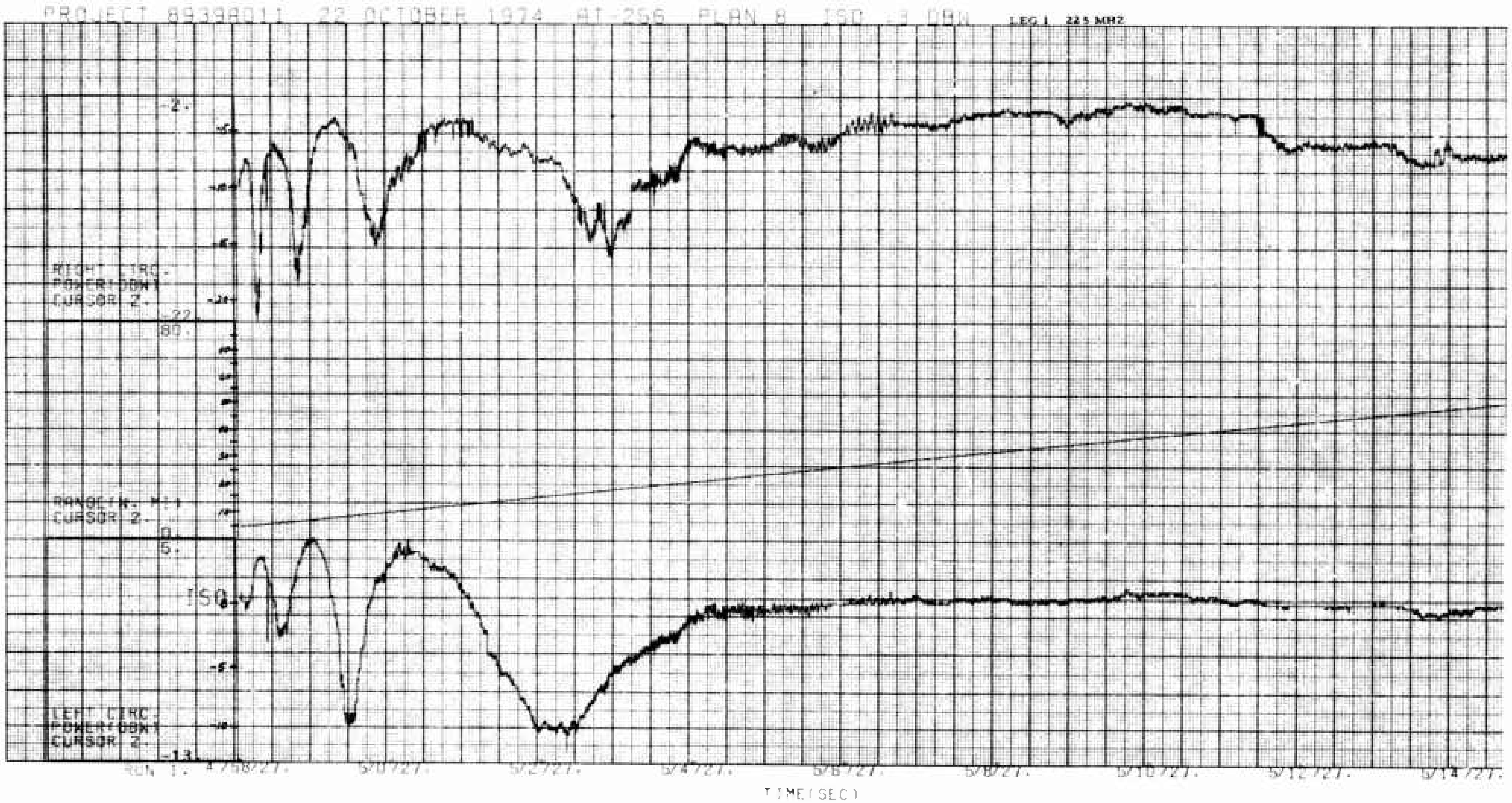

FIGURE D10 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

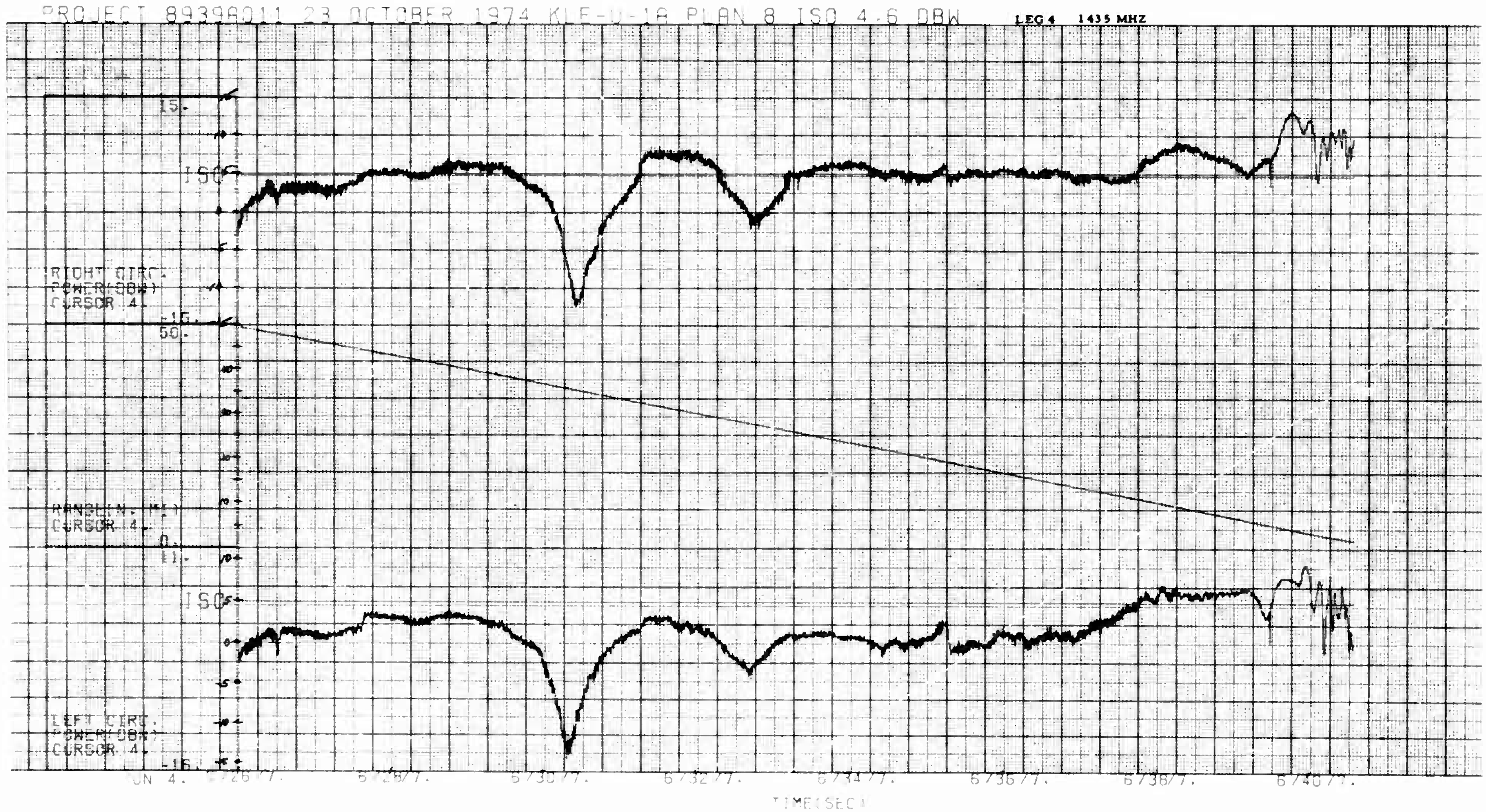

FIGURE D11 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

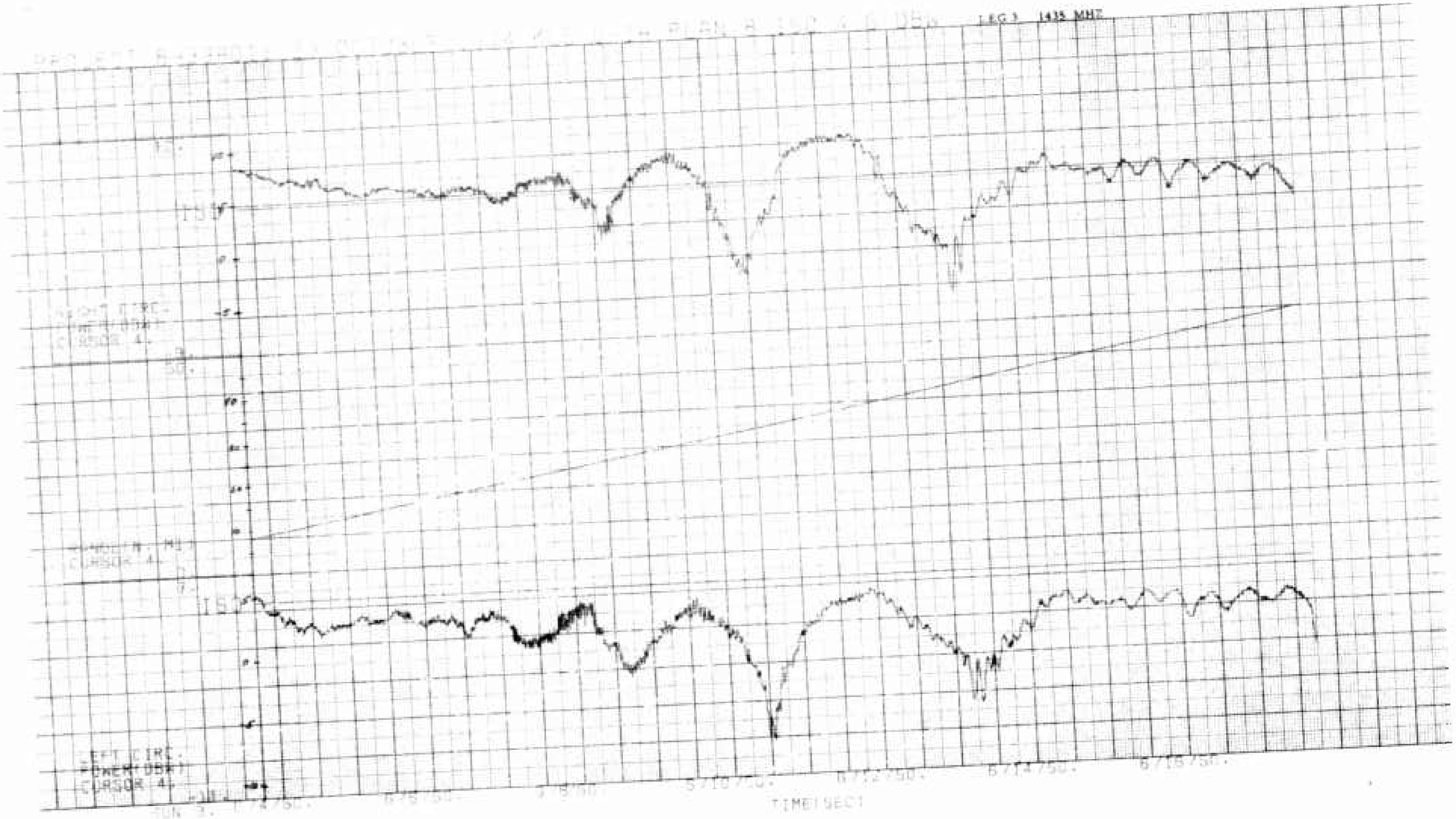

FIGURE D12 RADIAL FLIGHT PLOTS (GRIFFISS AFB TEST)

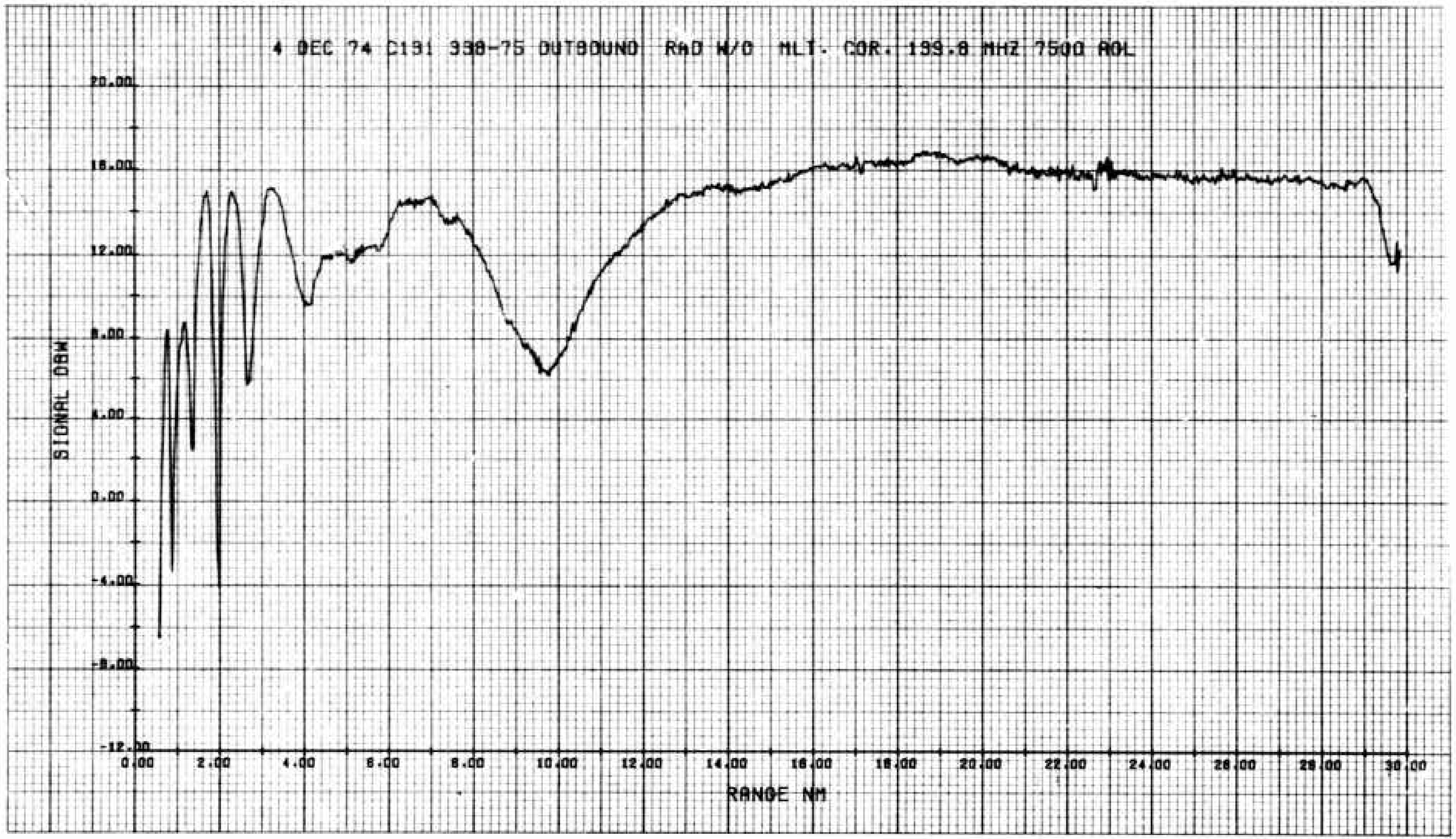

FIGURE D13 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

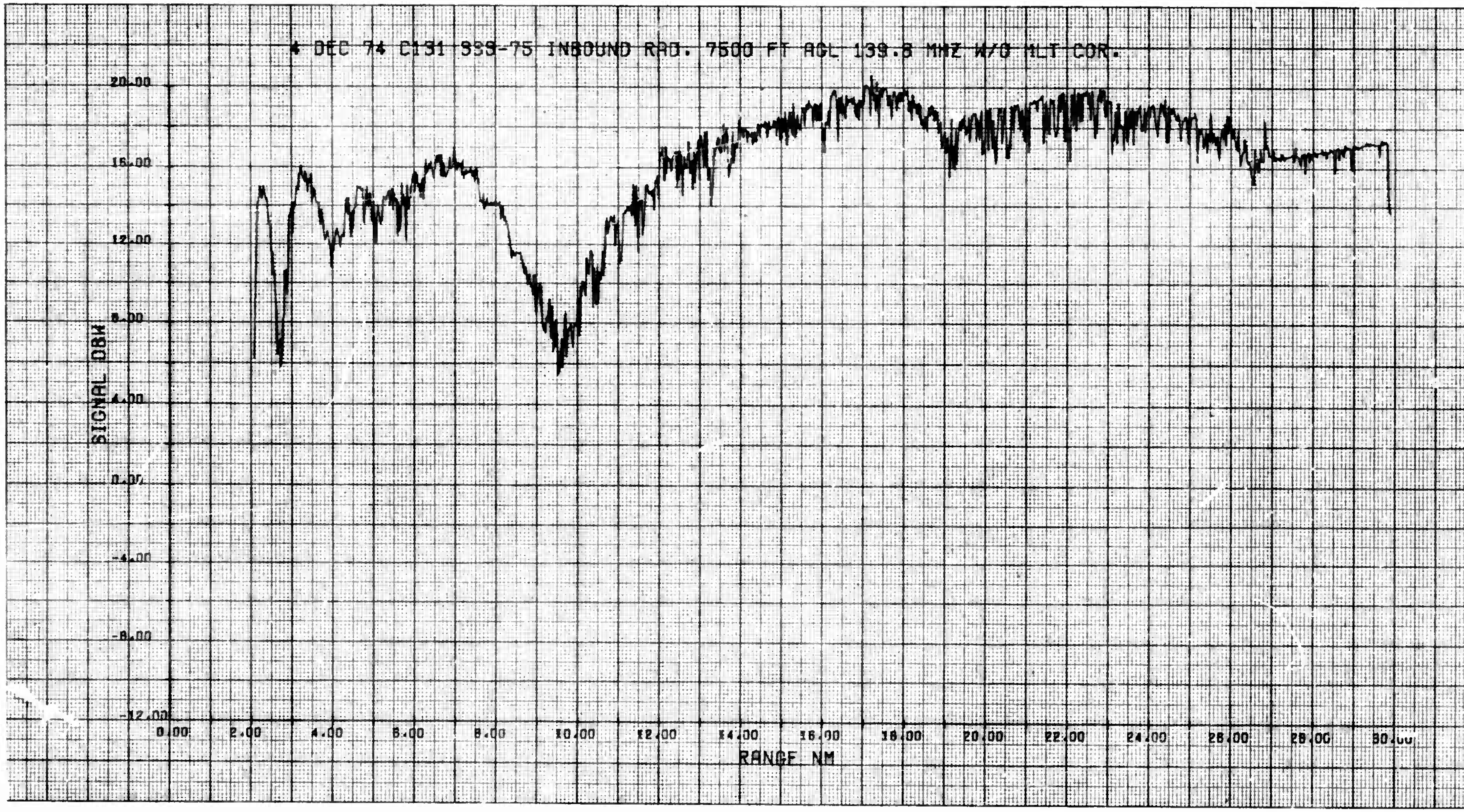

FIGURE D14 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

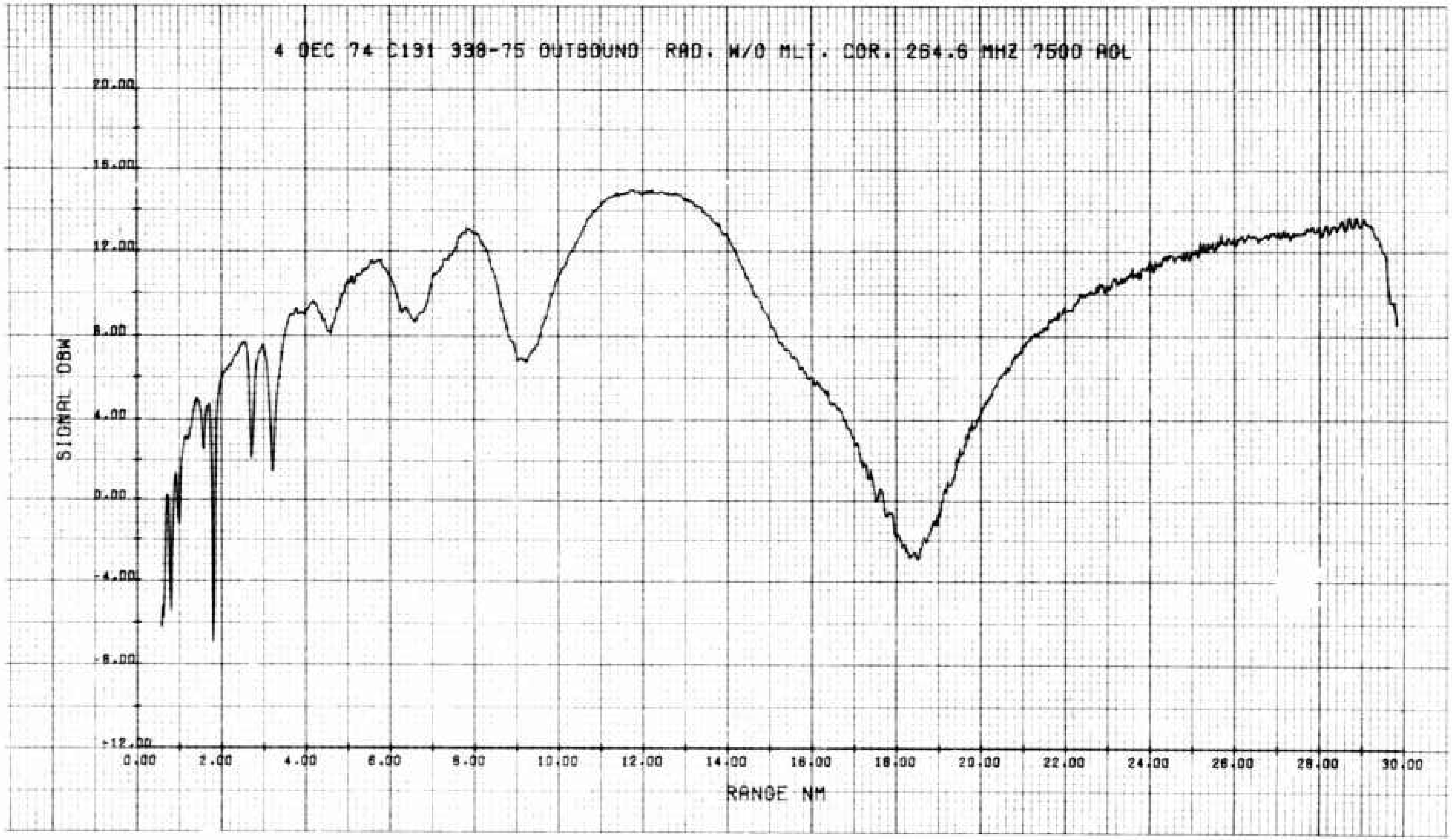

FIGURE D15 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

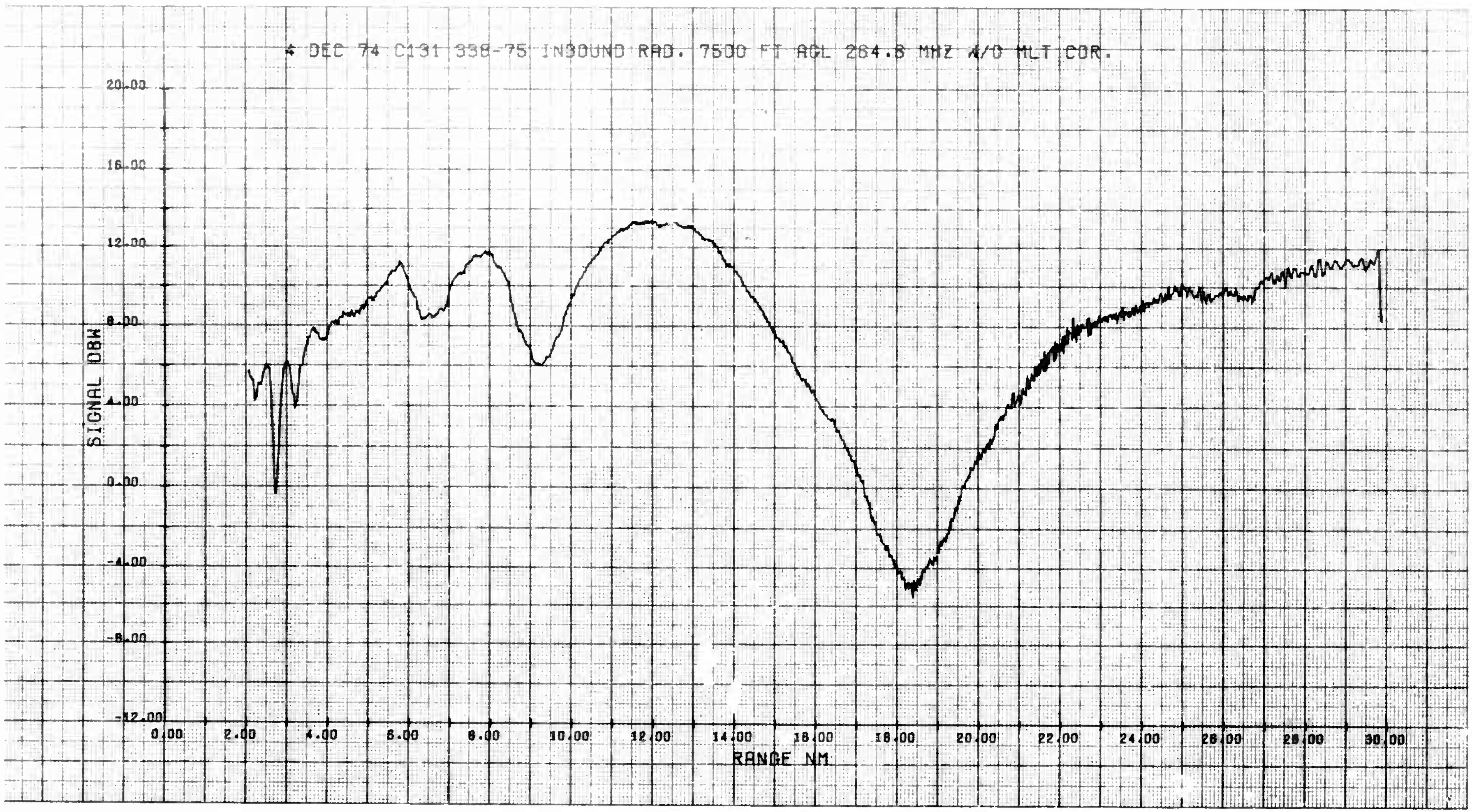

FIGURE D16 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

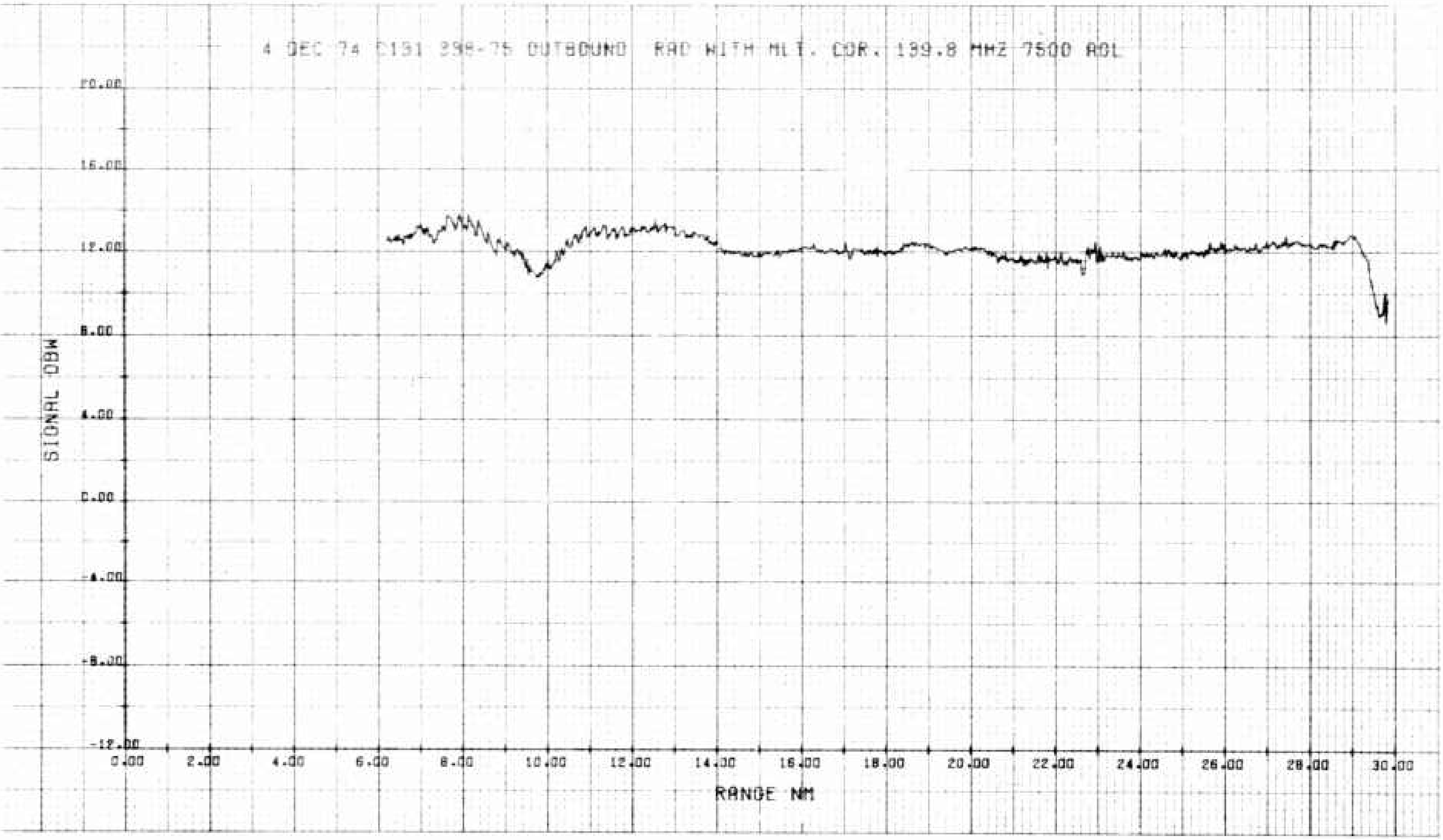

FIGURE D17 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

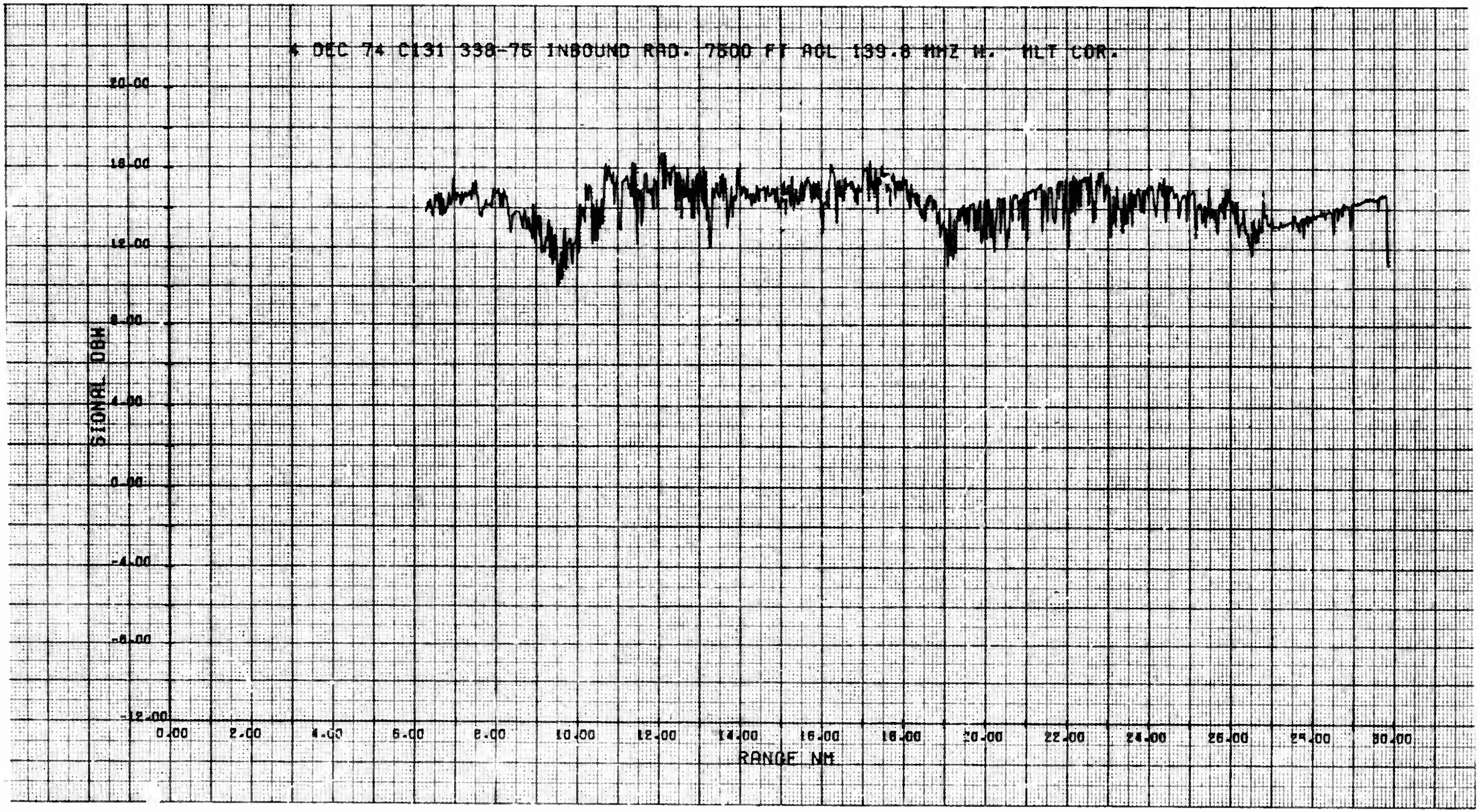

FIGURE D18 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

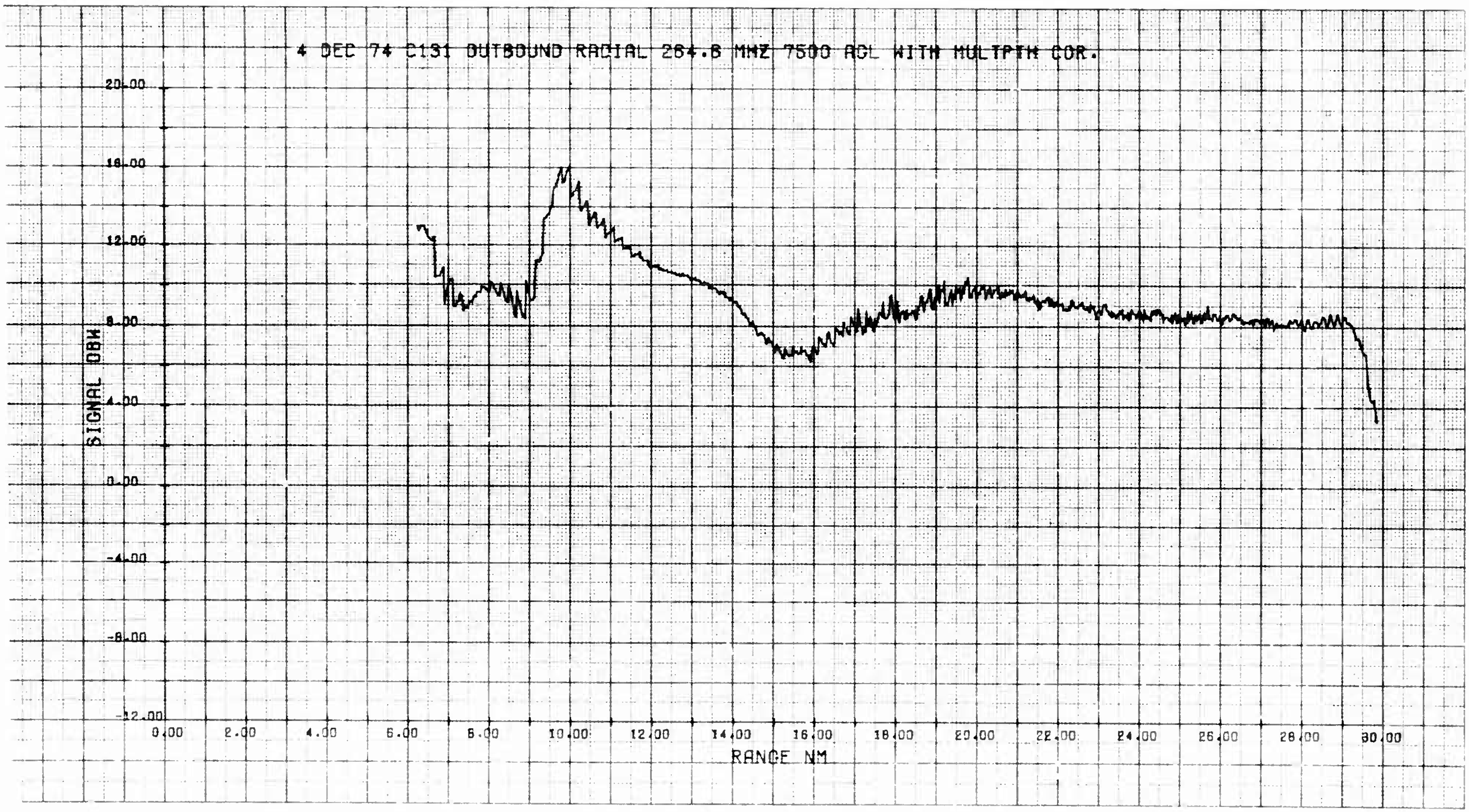

FIGURE D19 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

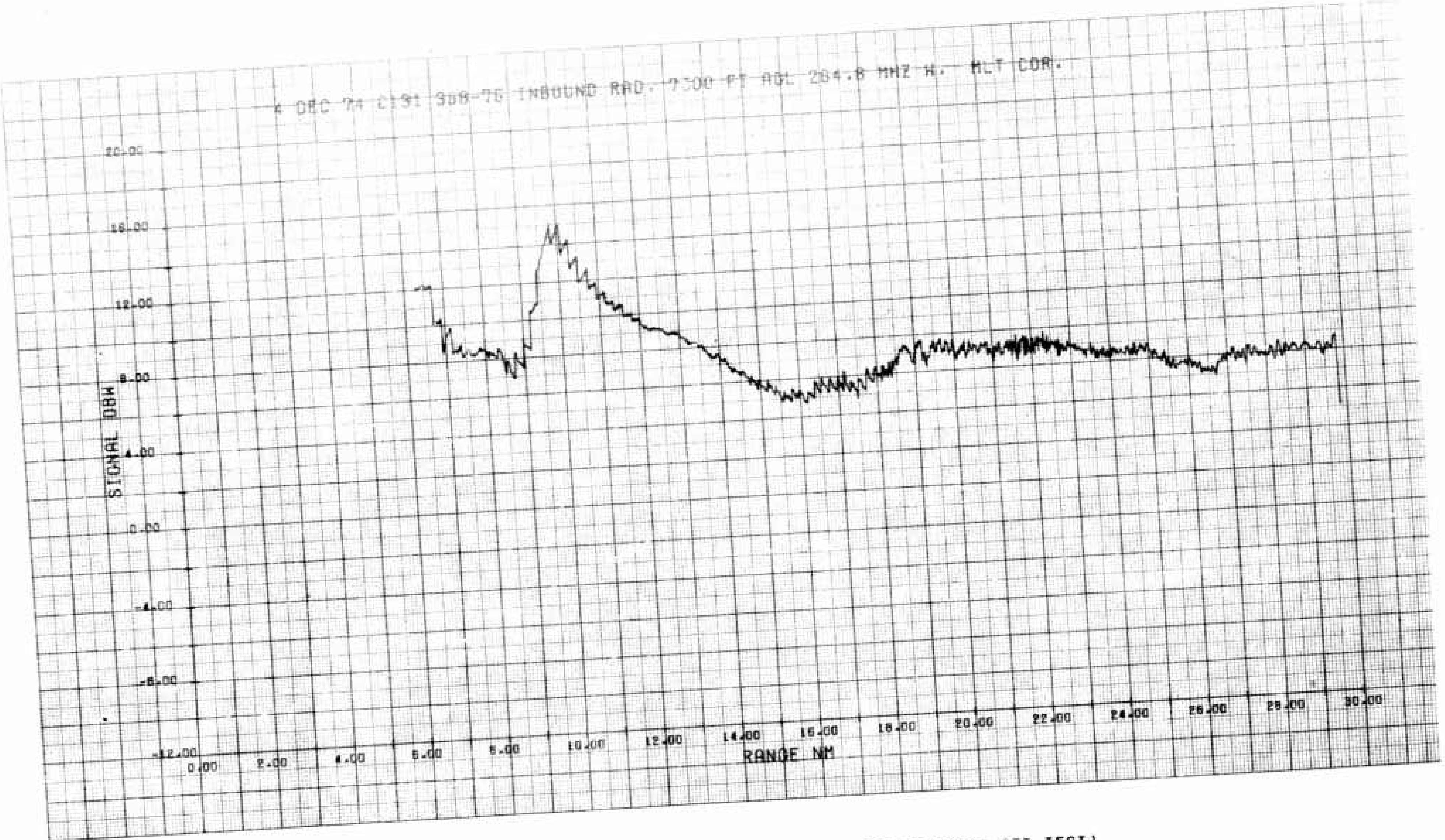

FIGURE D20 RADIAL FLIGHT PLOTS (EDWARDS AFB TEST)

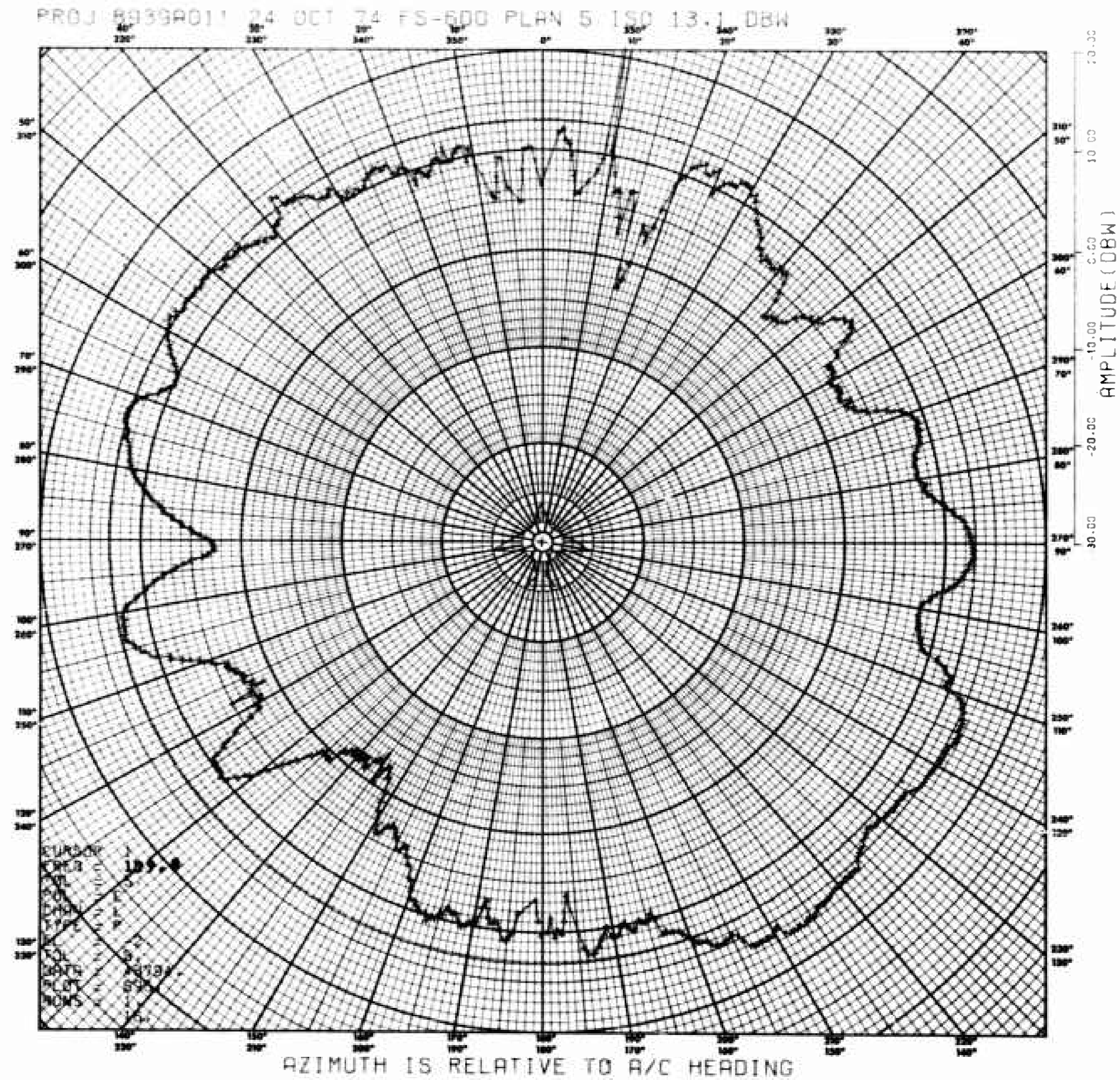

FIGURE D21 VHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

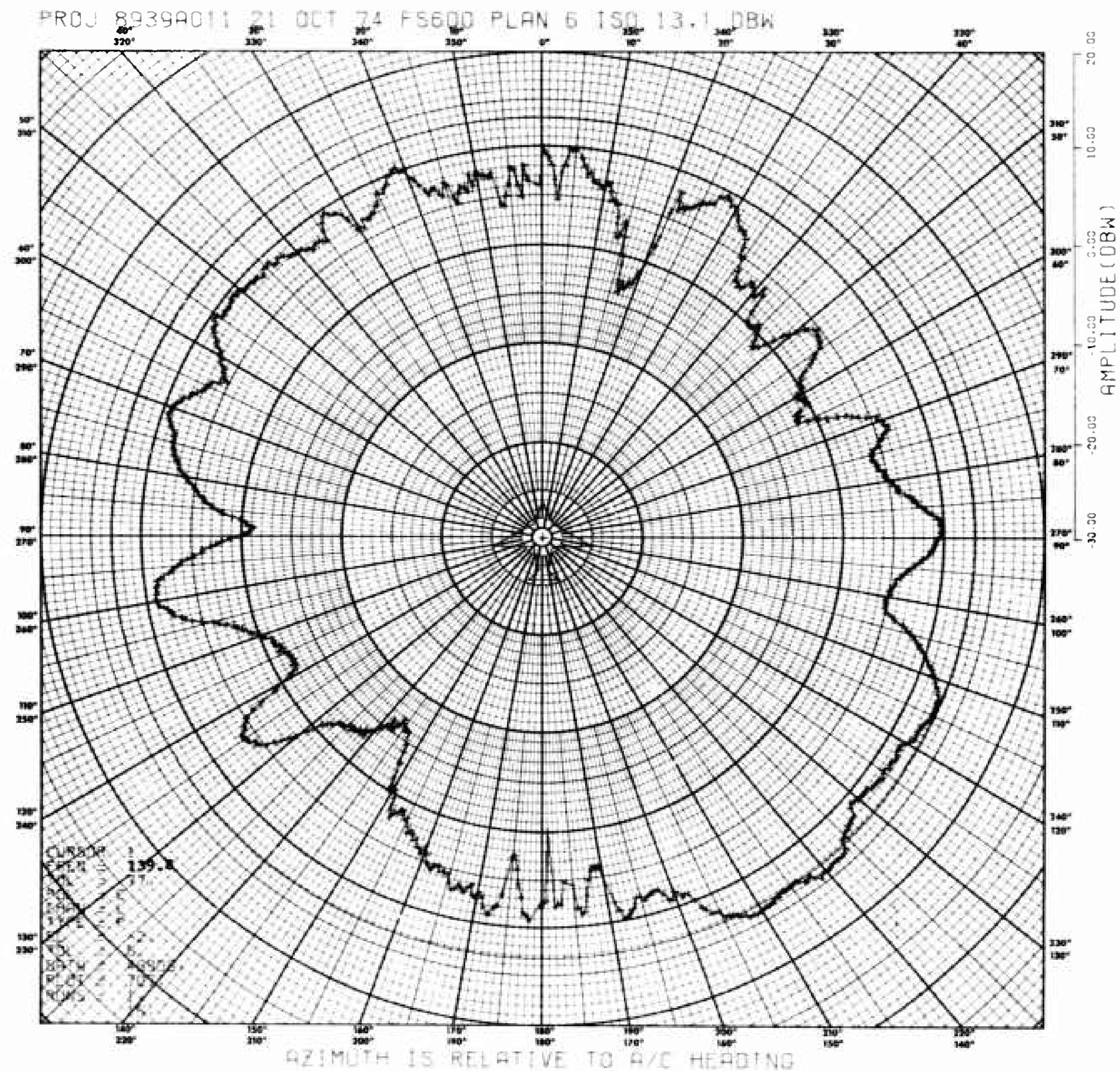

FIGURE D22 VHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

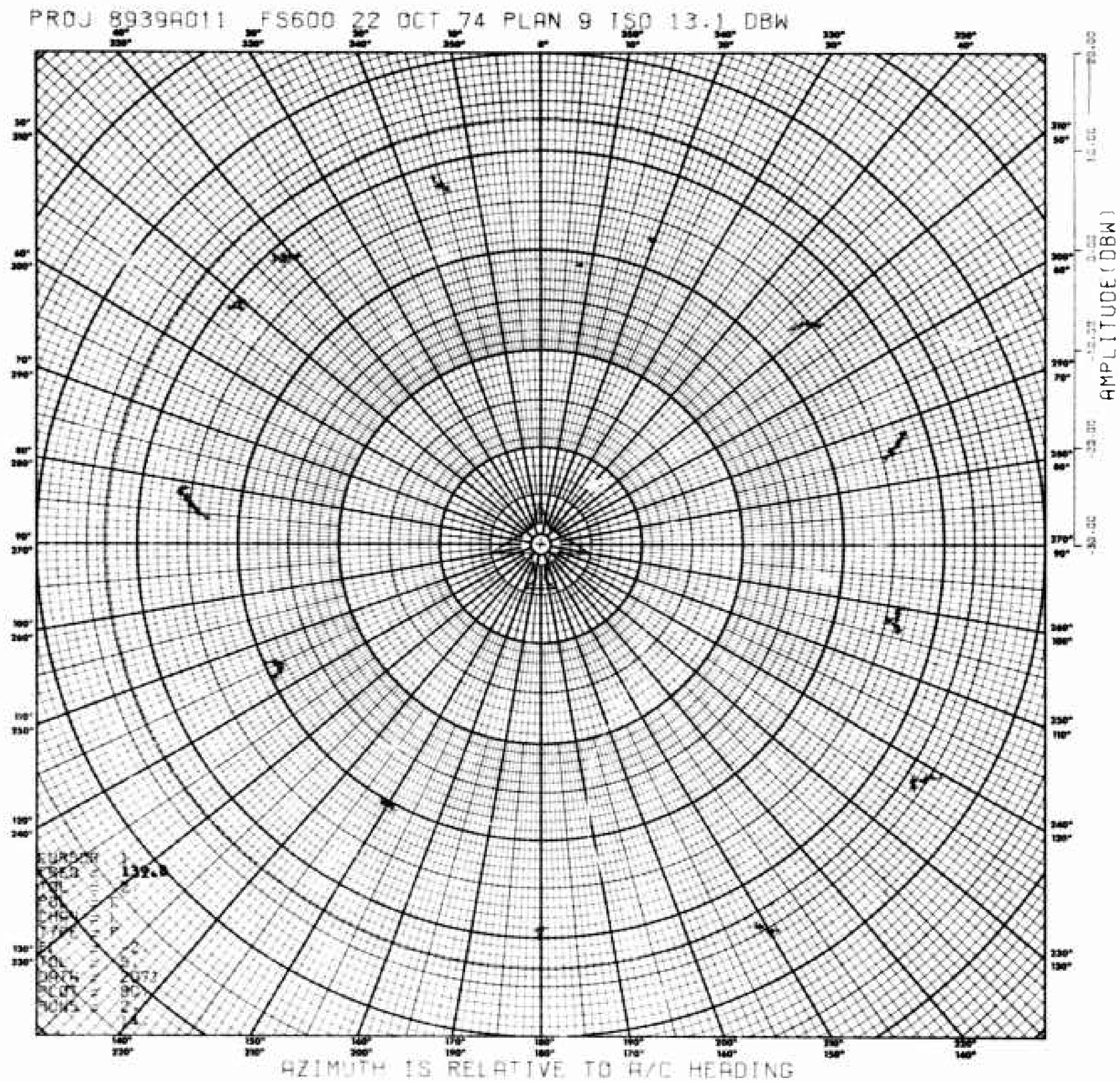

FIGURE D23 VHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

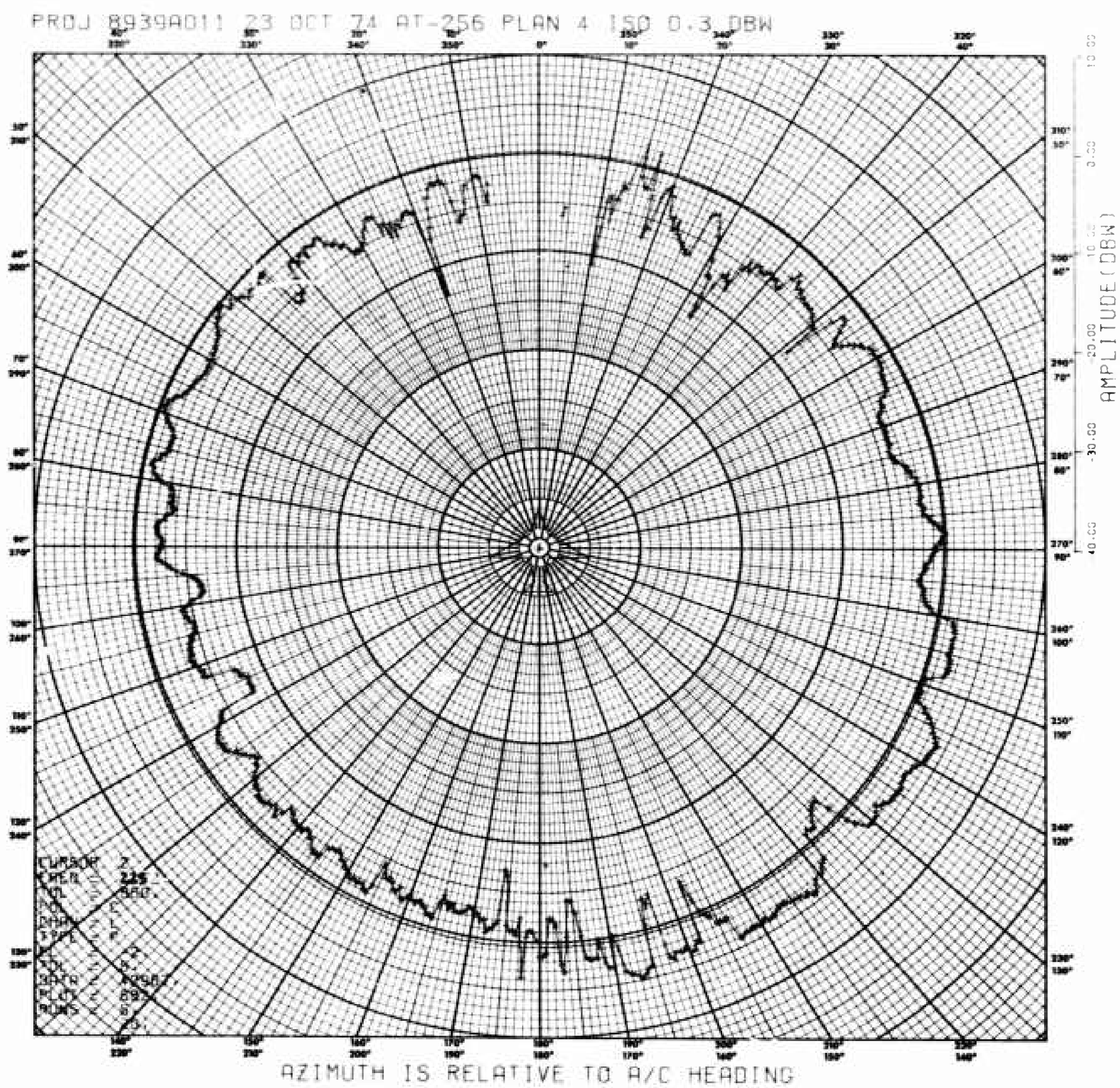

FIGURE D24 UHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

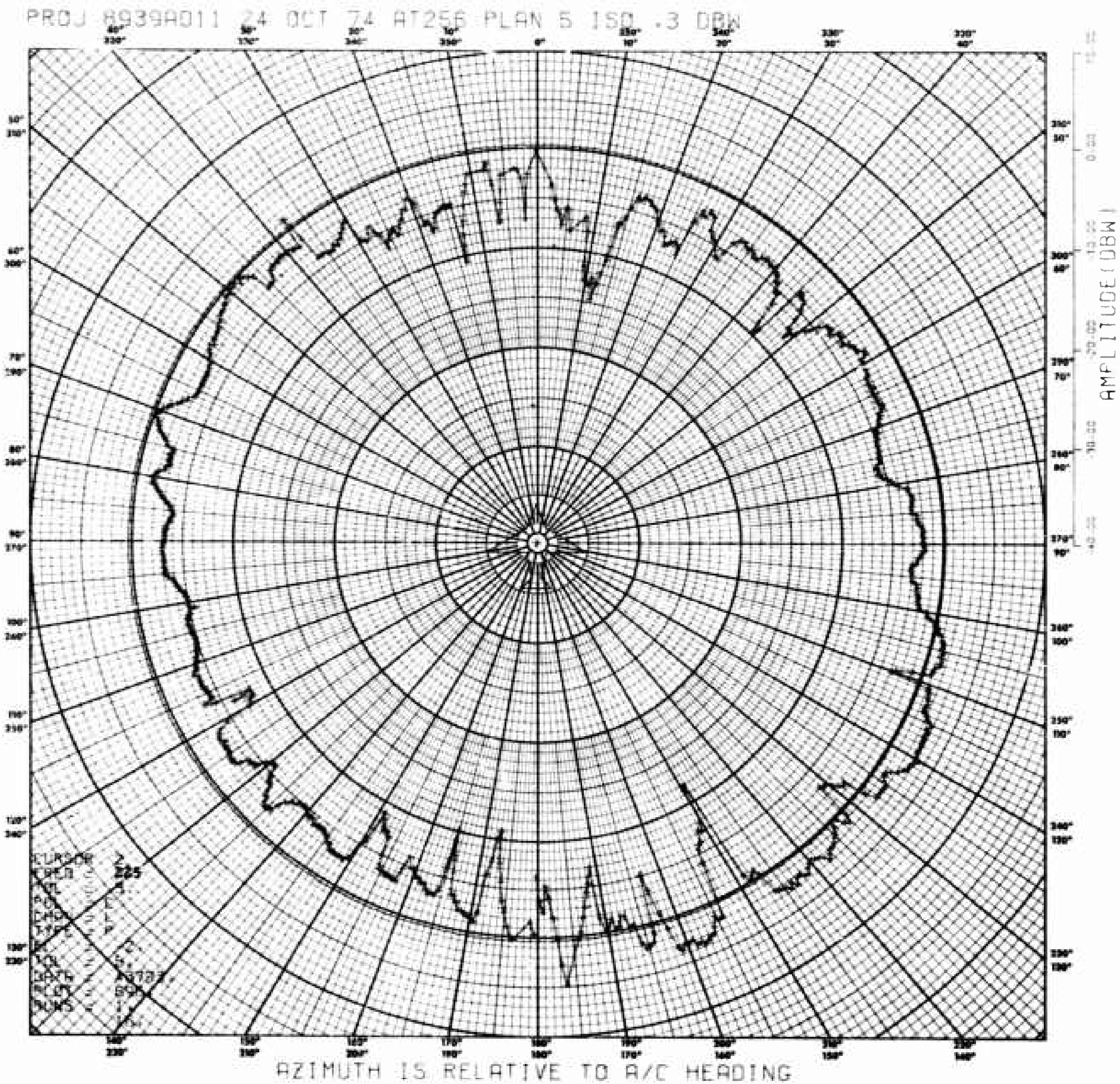

FIGURE 025 UHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

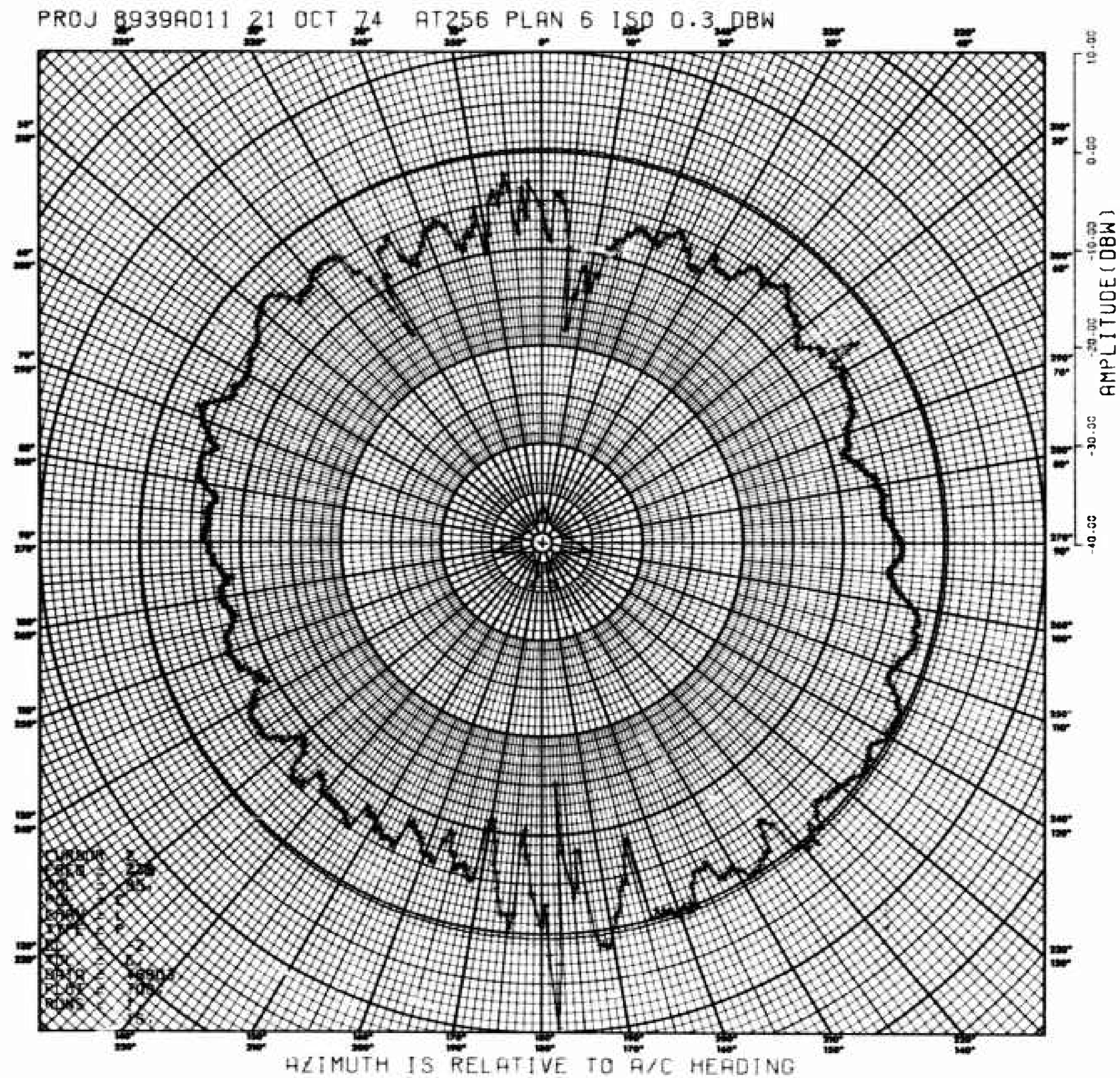

FIGURE D26 UHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

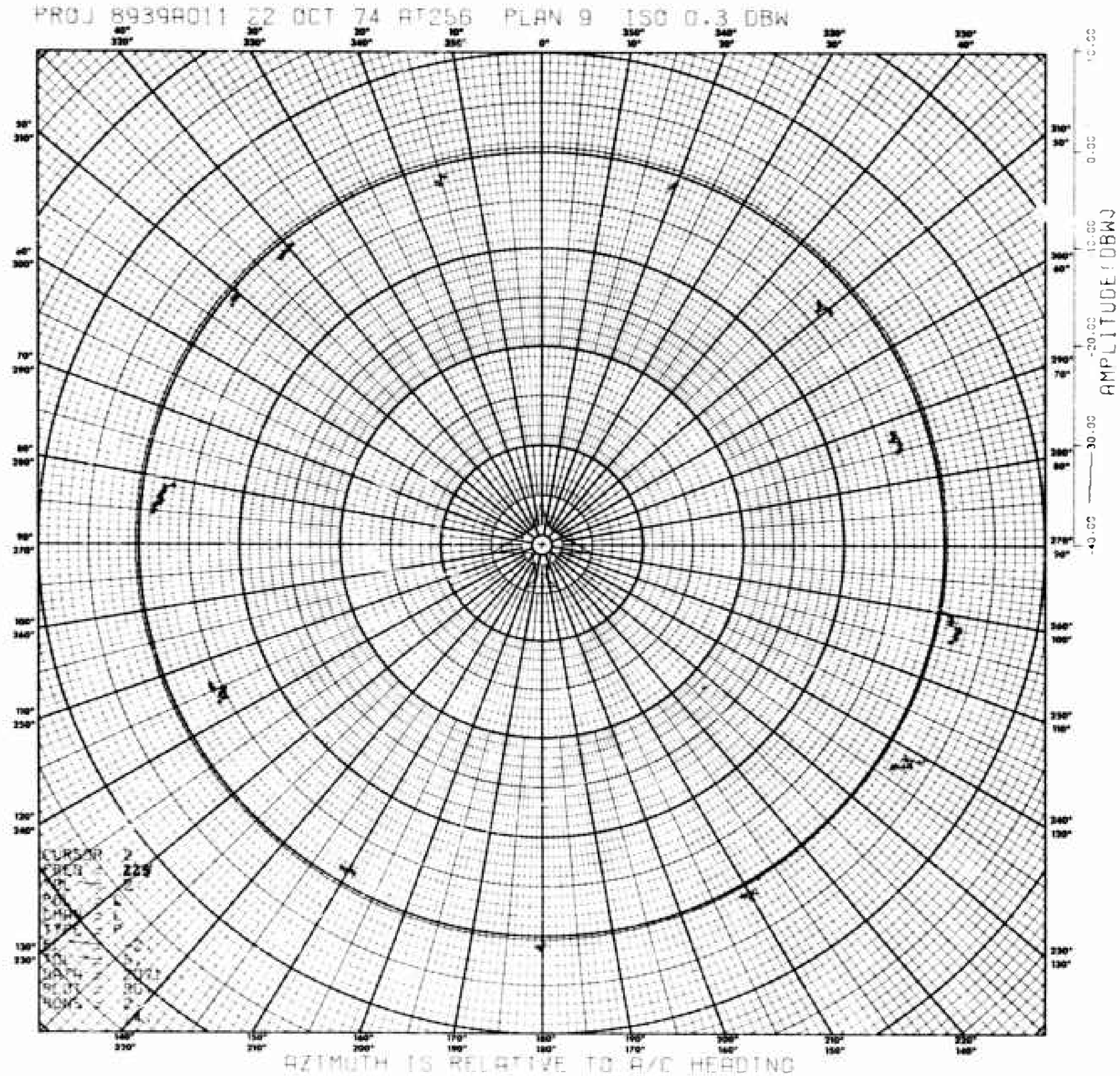

FIGURE D27 UHF ANTENNA PATTERNS (GRIFFISS AFB TEST)

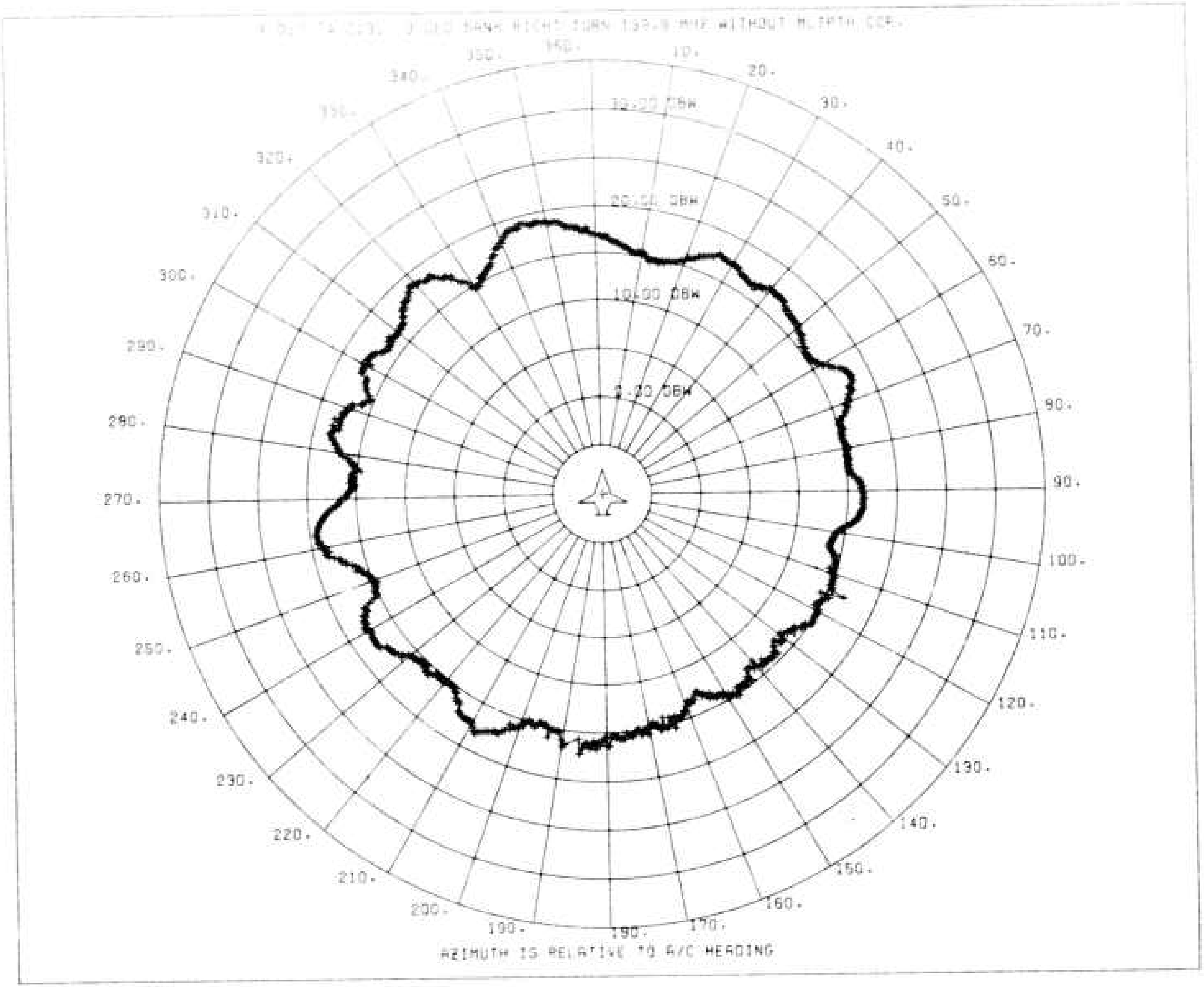

FIGURE D28 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

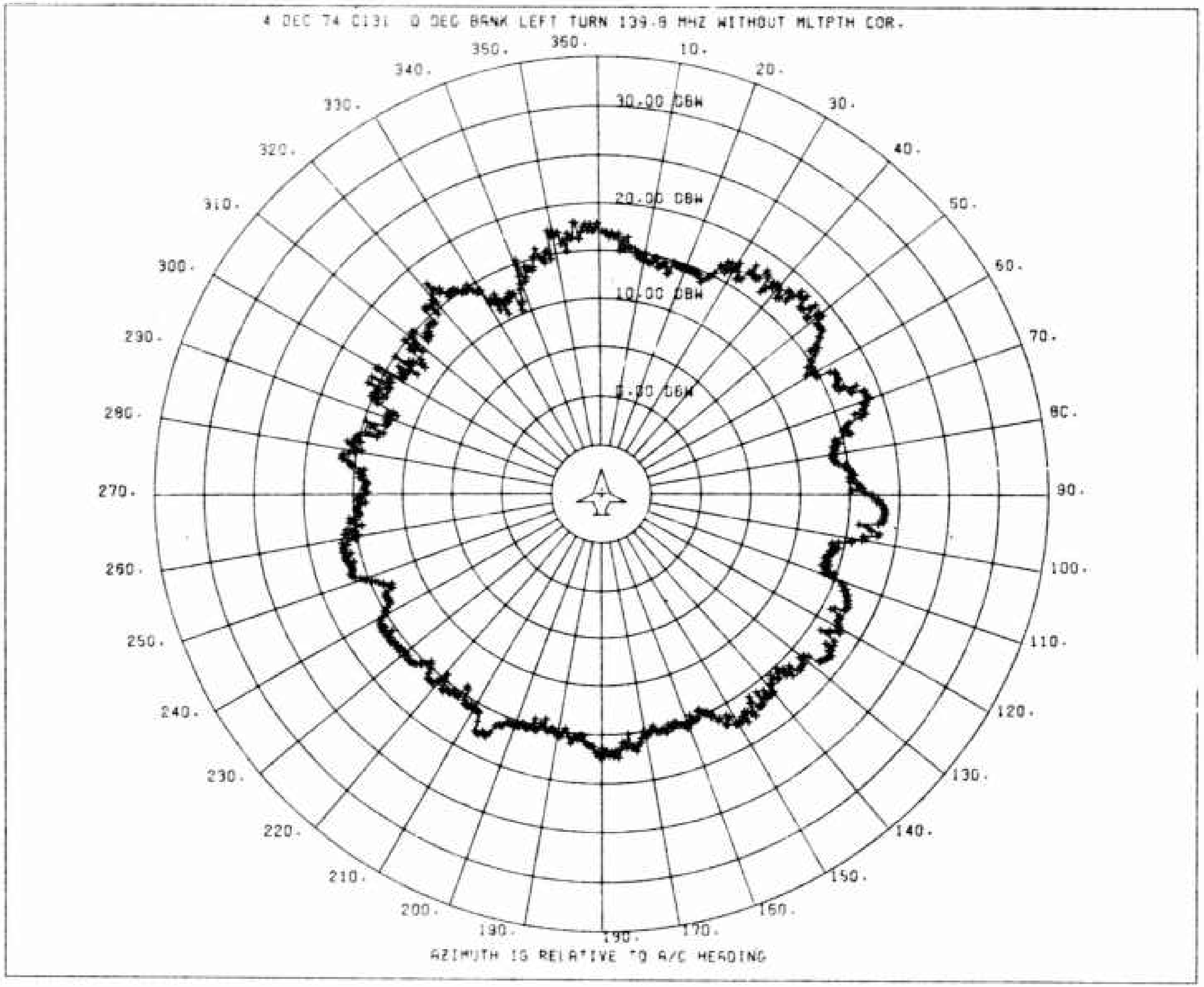

FIGURE D29 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

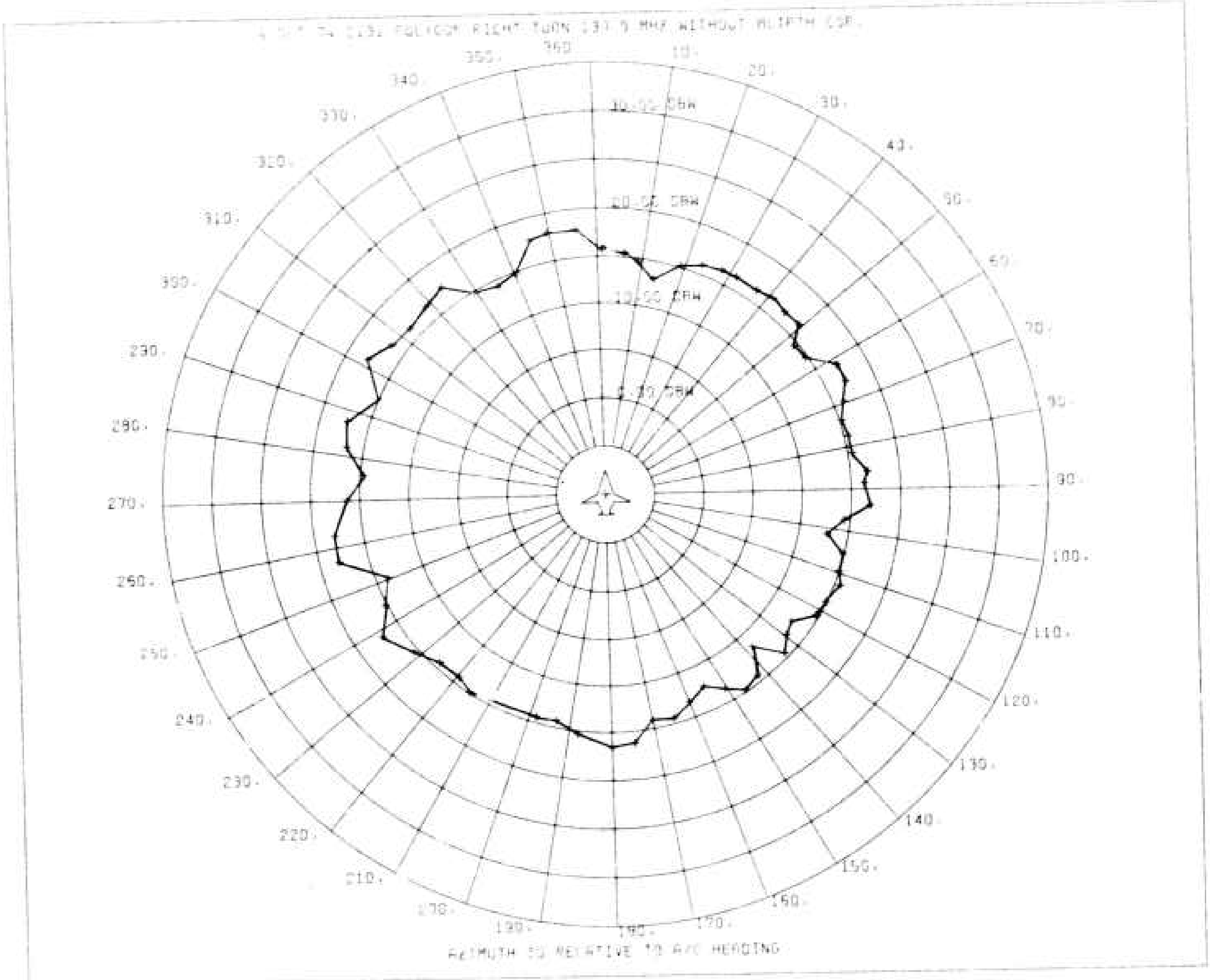

FIGURE D30 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

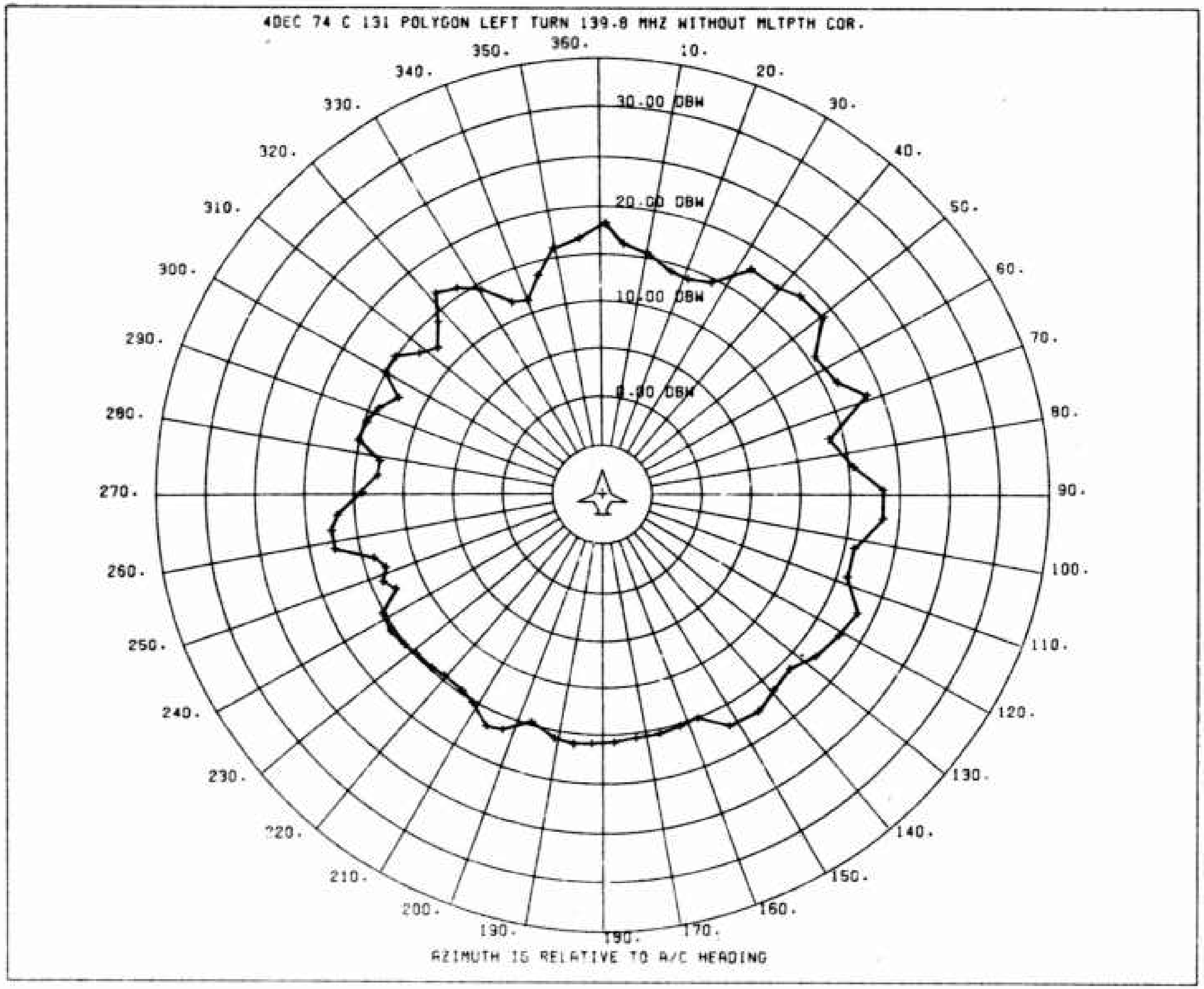

FIGURE D31 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

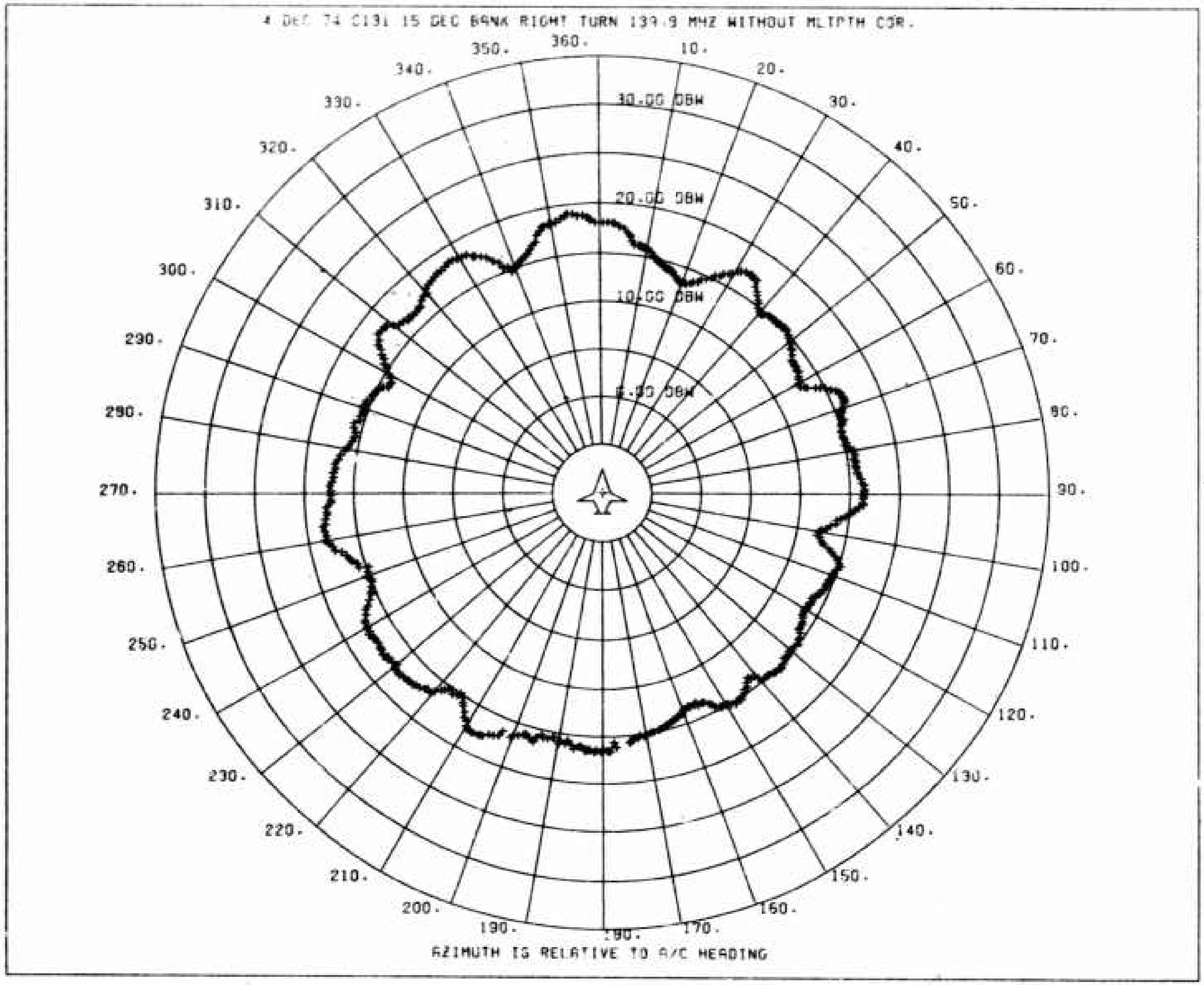

FIGURE D32 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

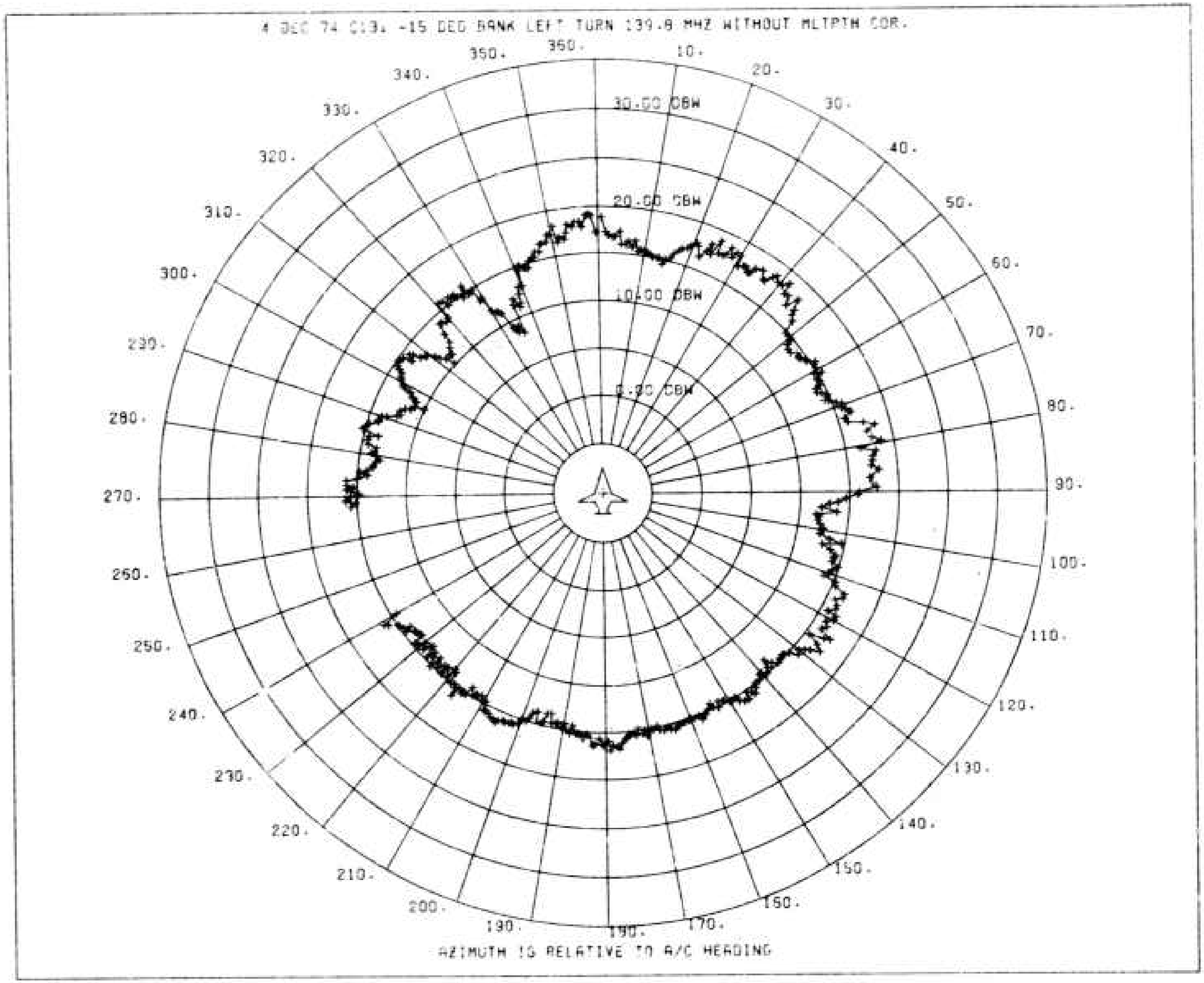

FIGURE D33 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

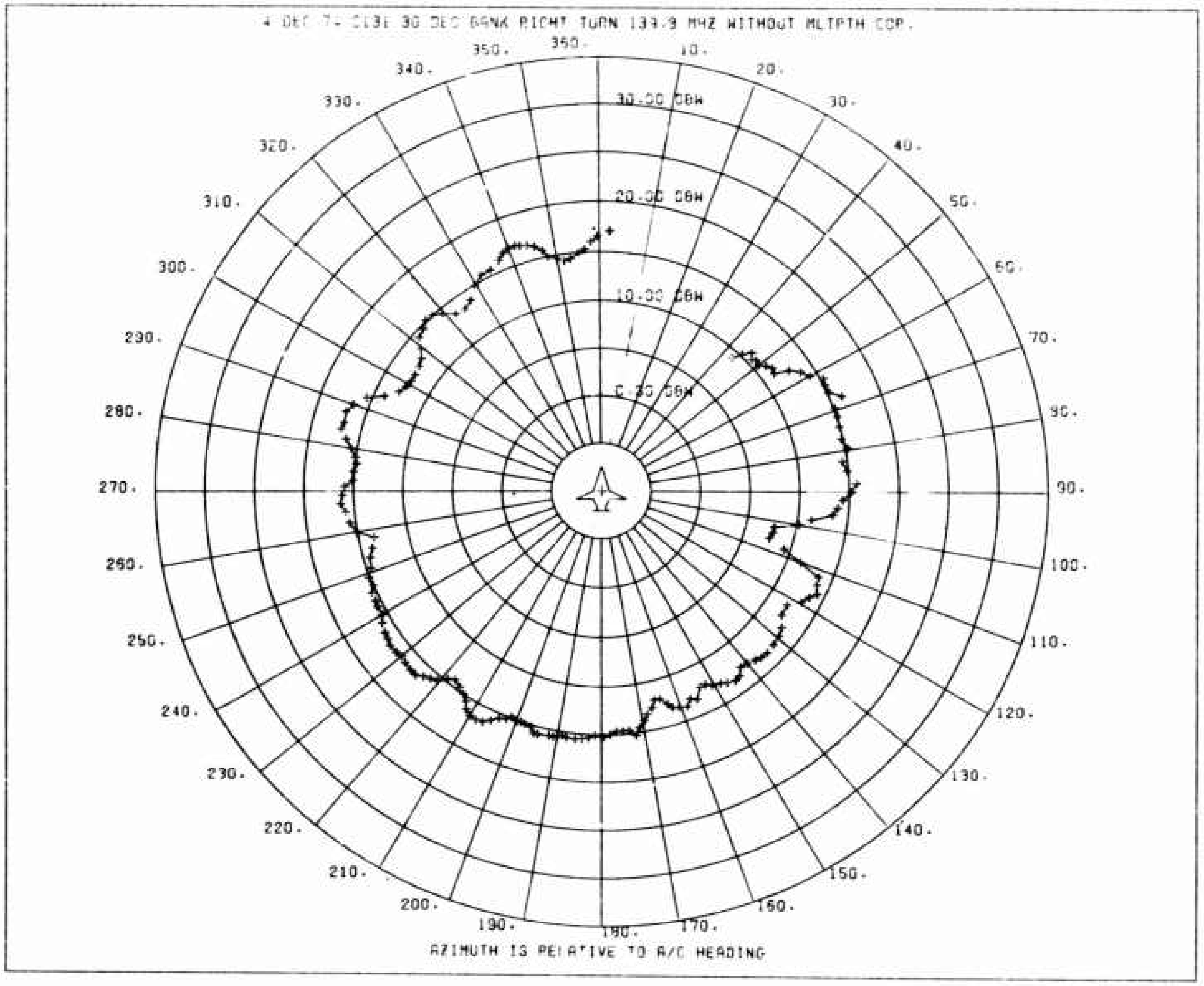

FIGURE D34 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

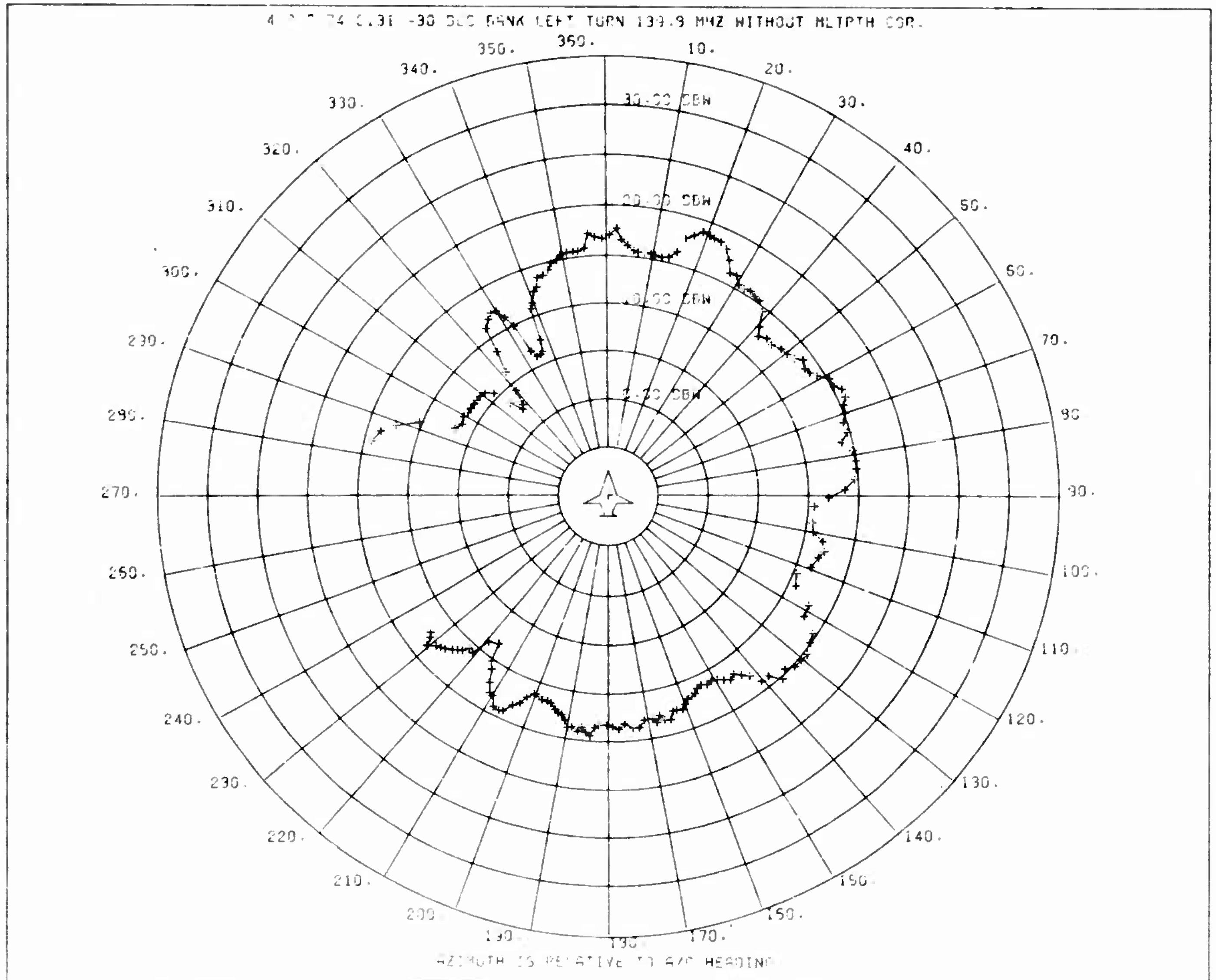

FIGURE D35 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

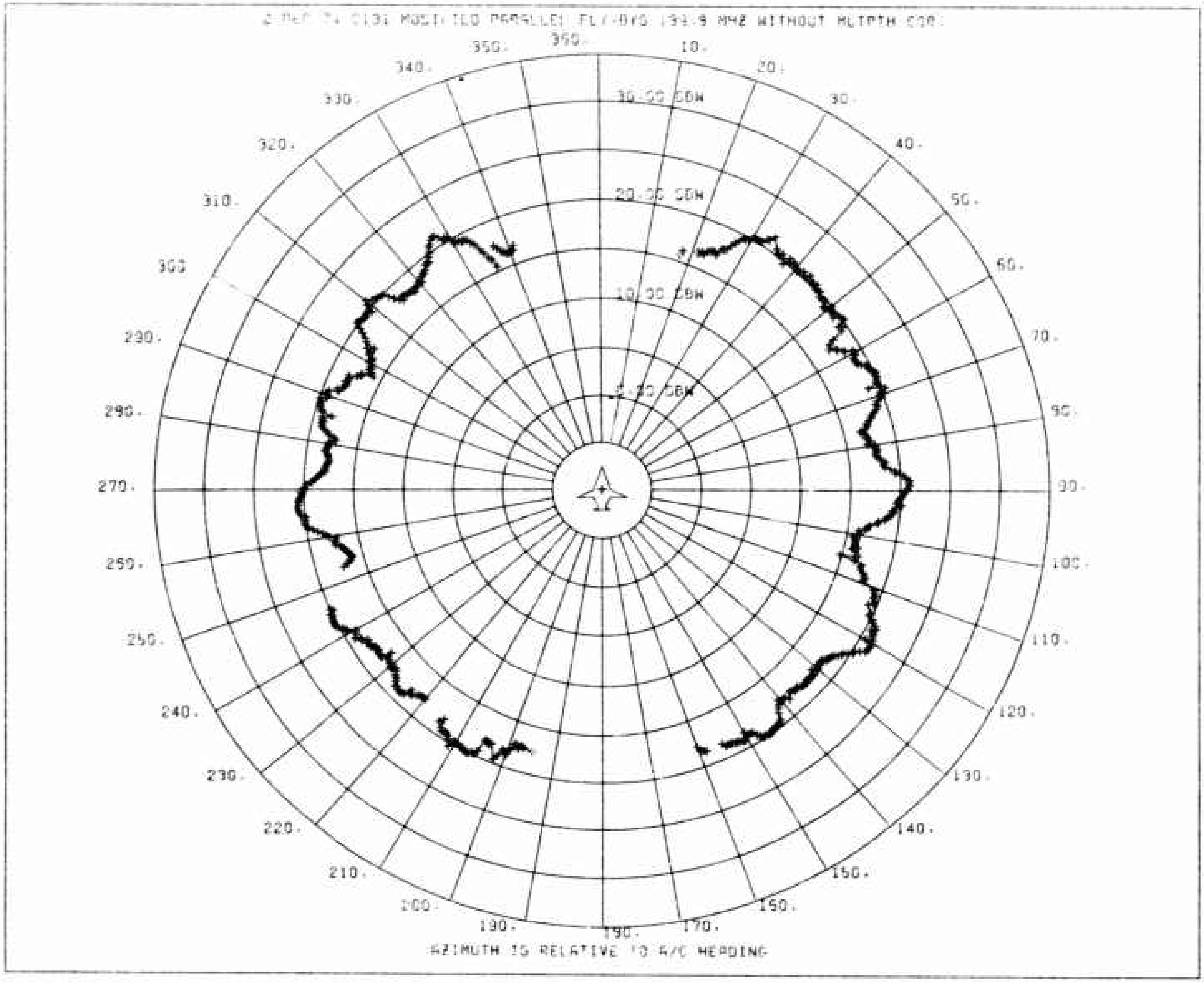

FIGURE 036 VHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

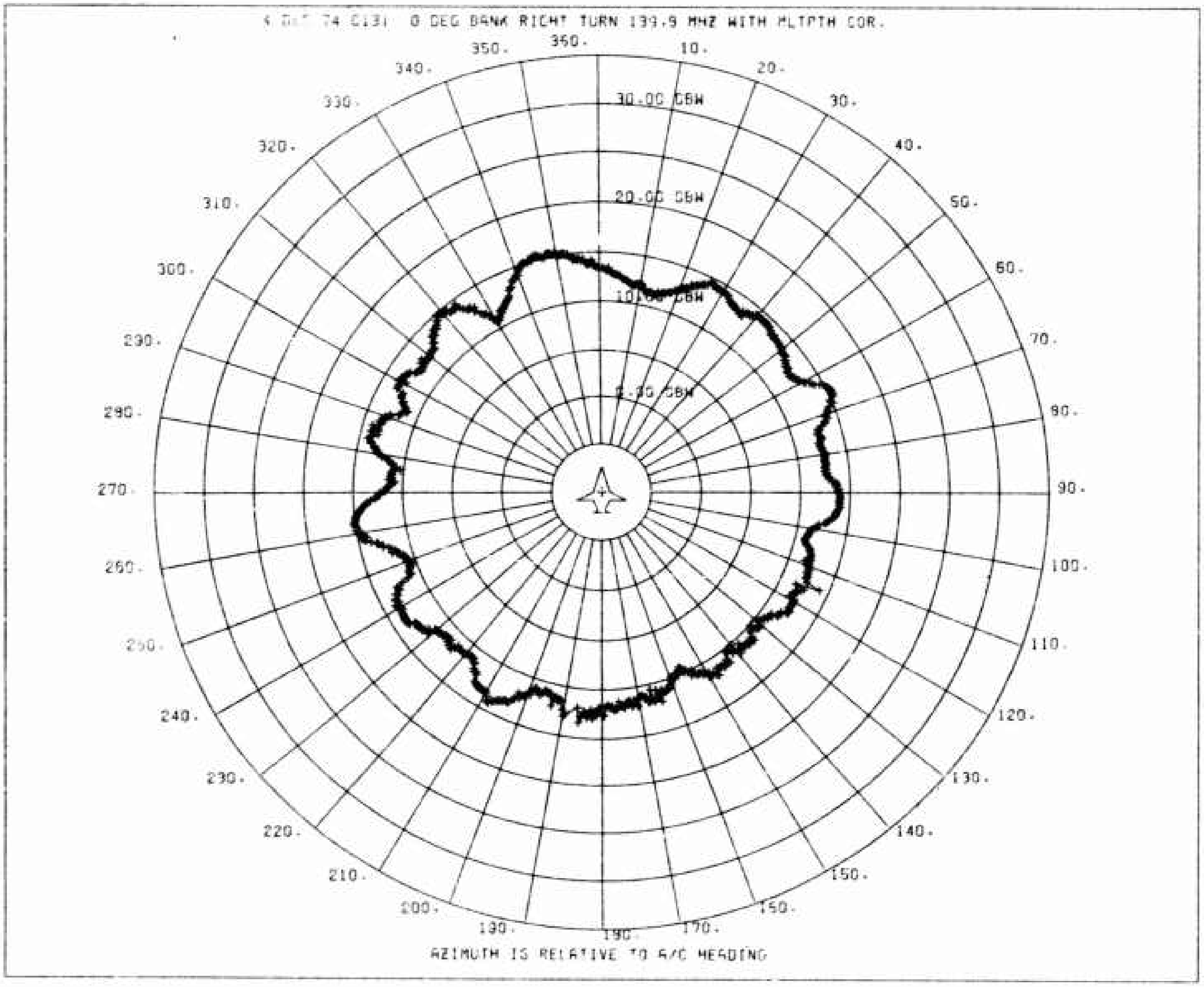

FIGURE D37 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

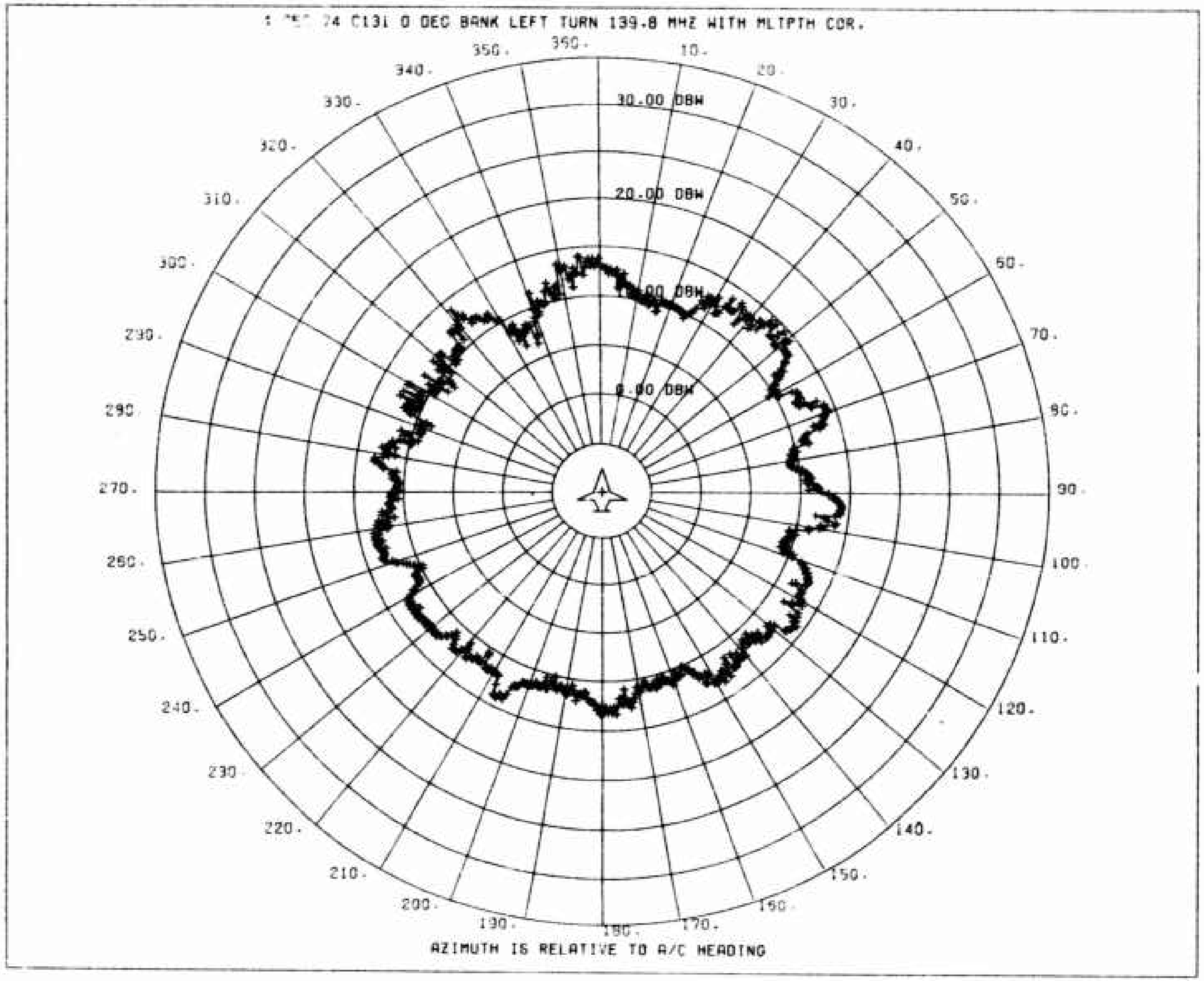

FIGURE D38 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

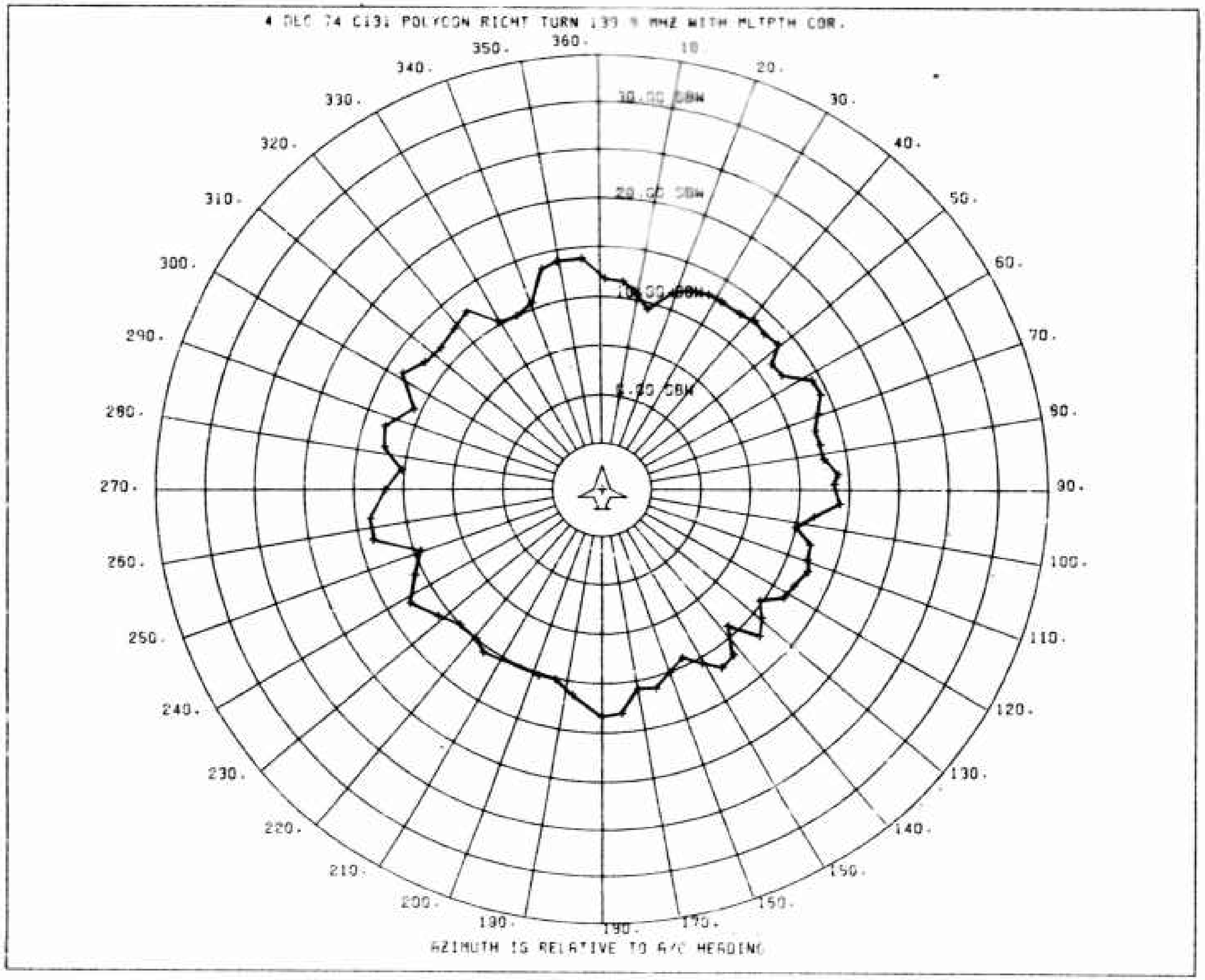

FIGURE D39 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

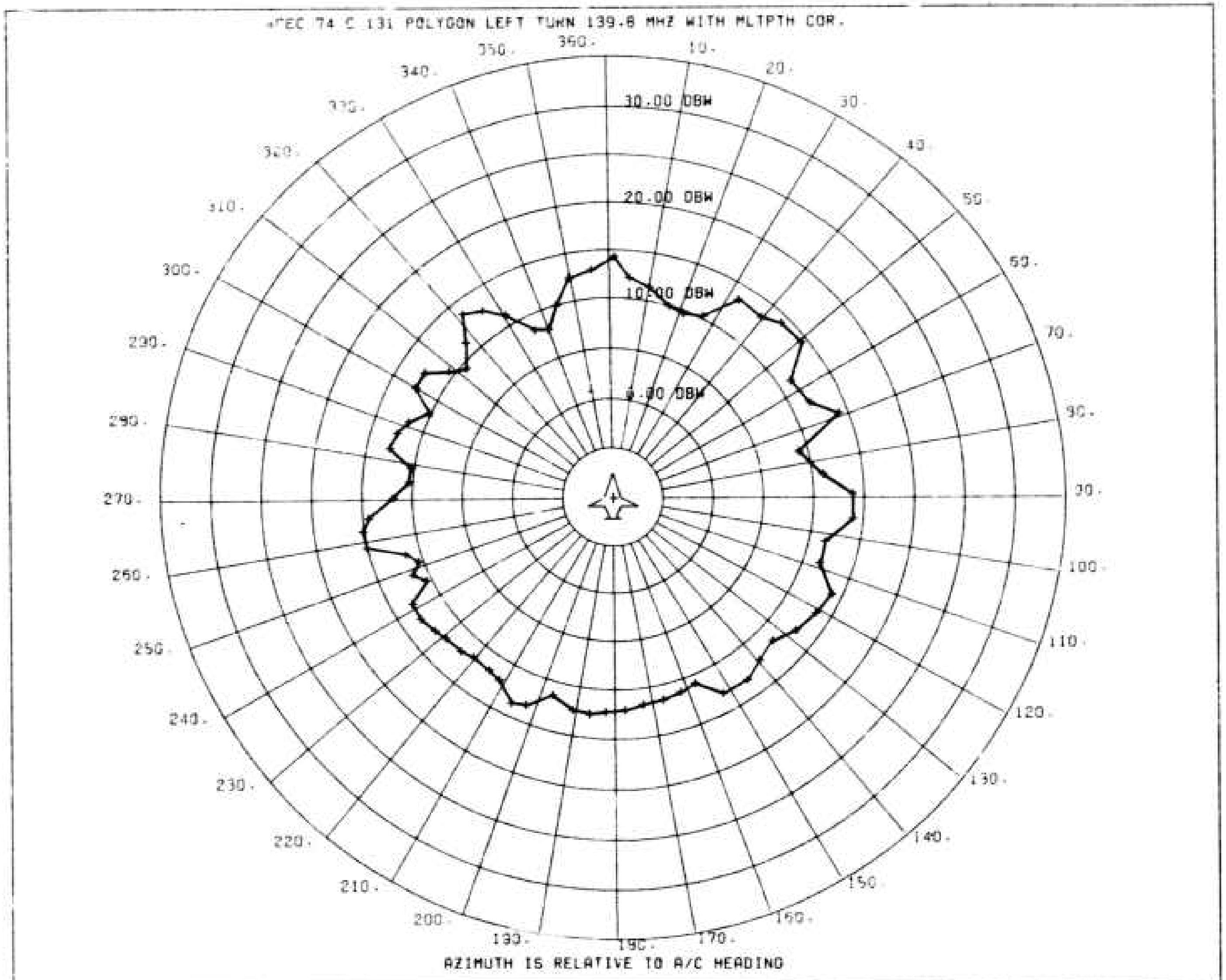

FIGURE D40 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

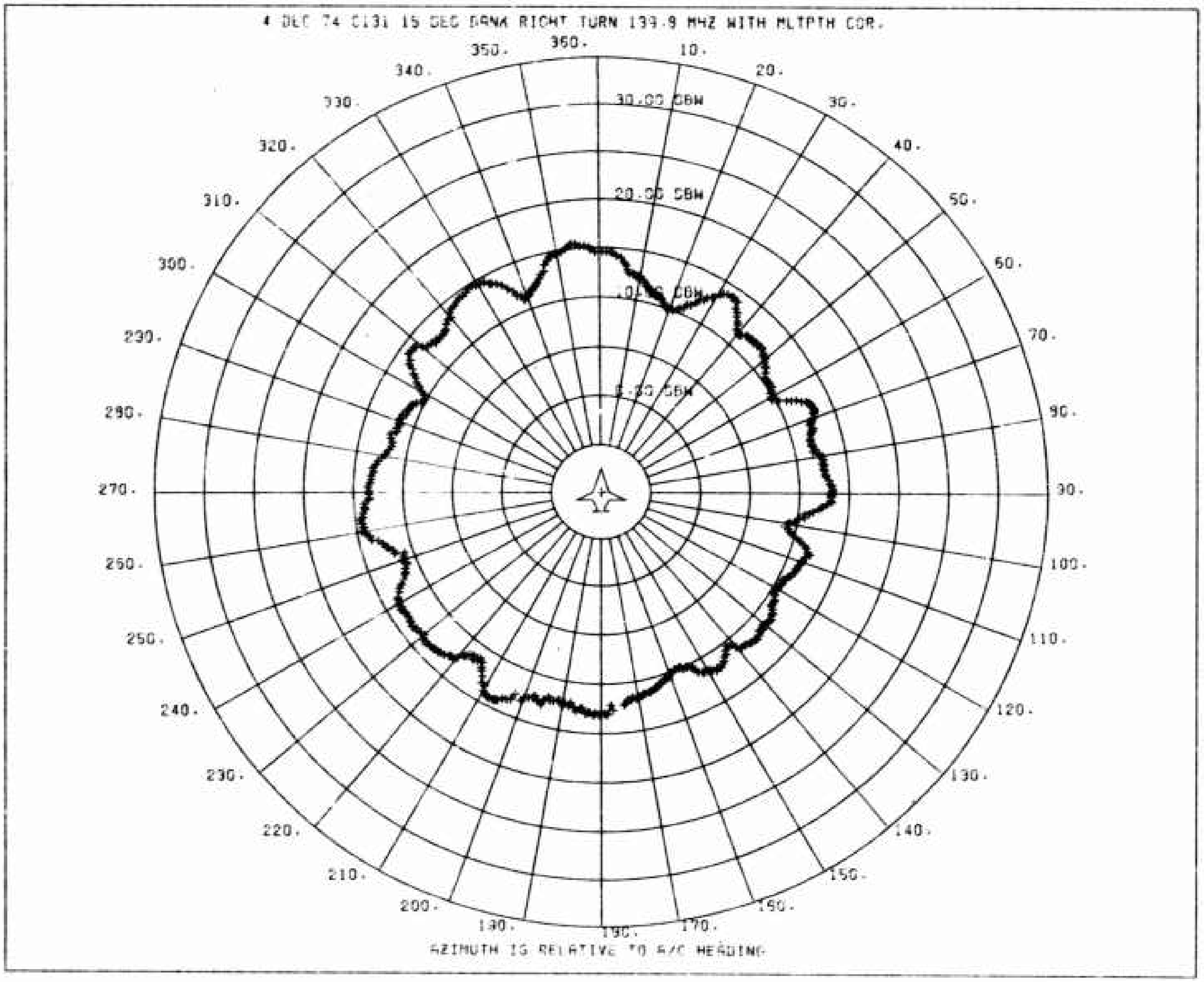

FIGURE 041 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

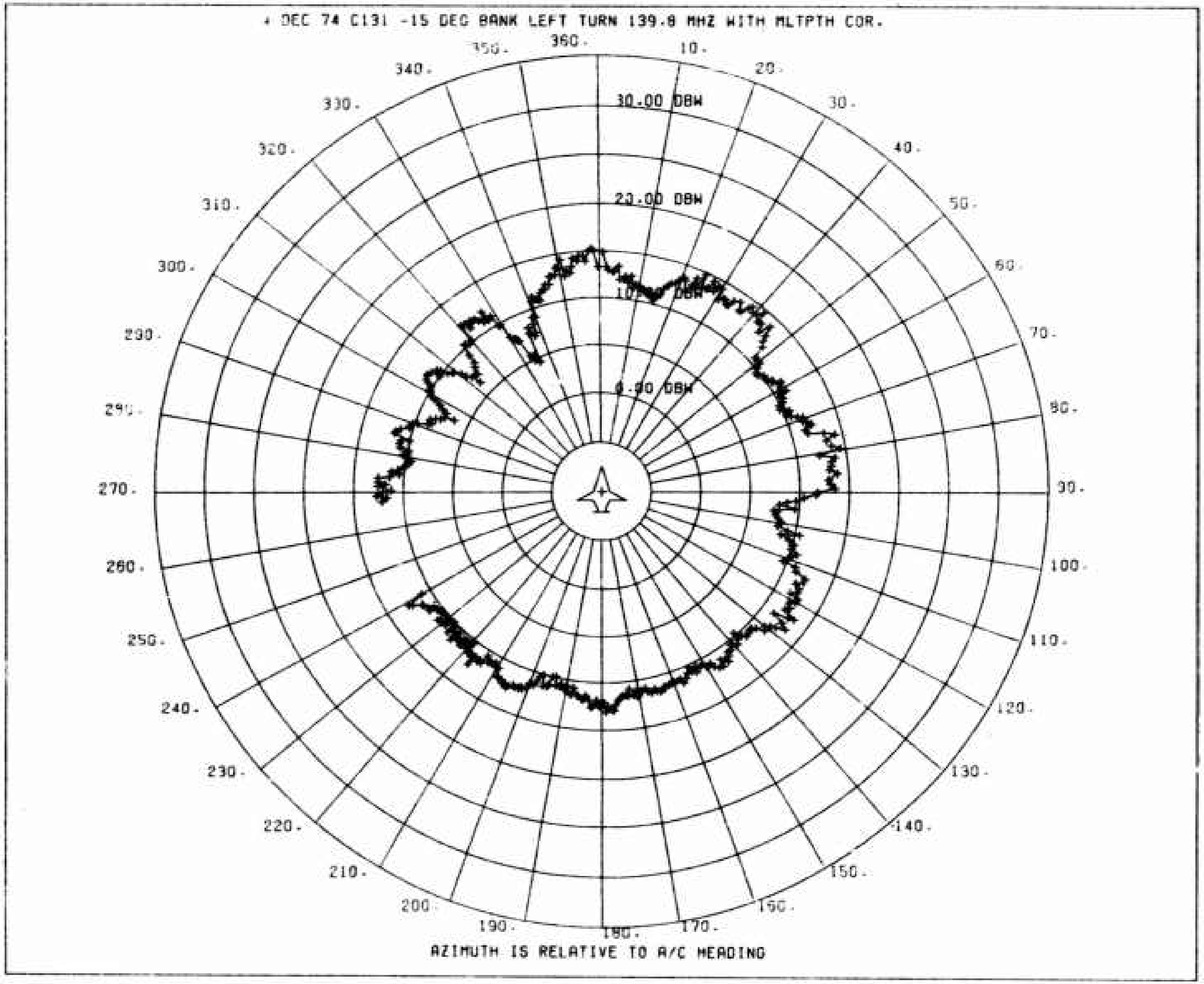

FIGURE D42 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

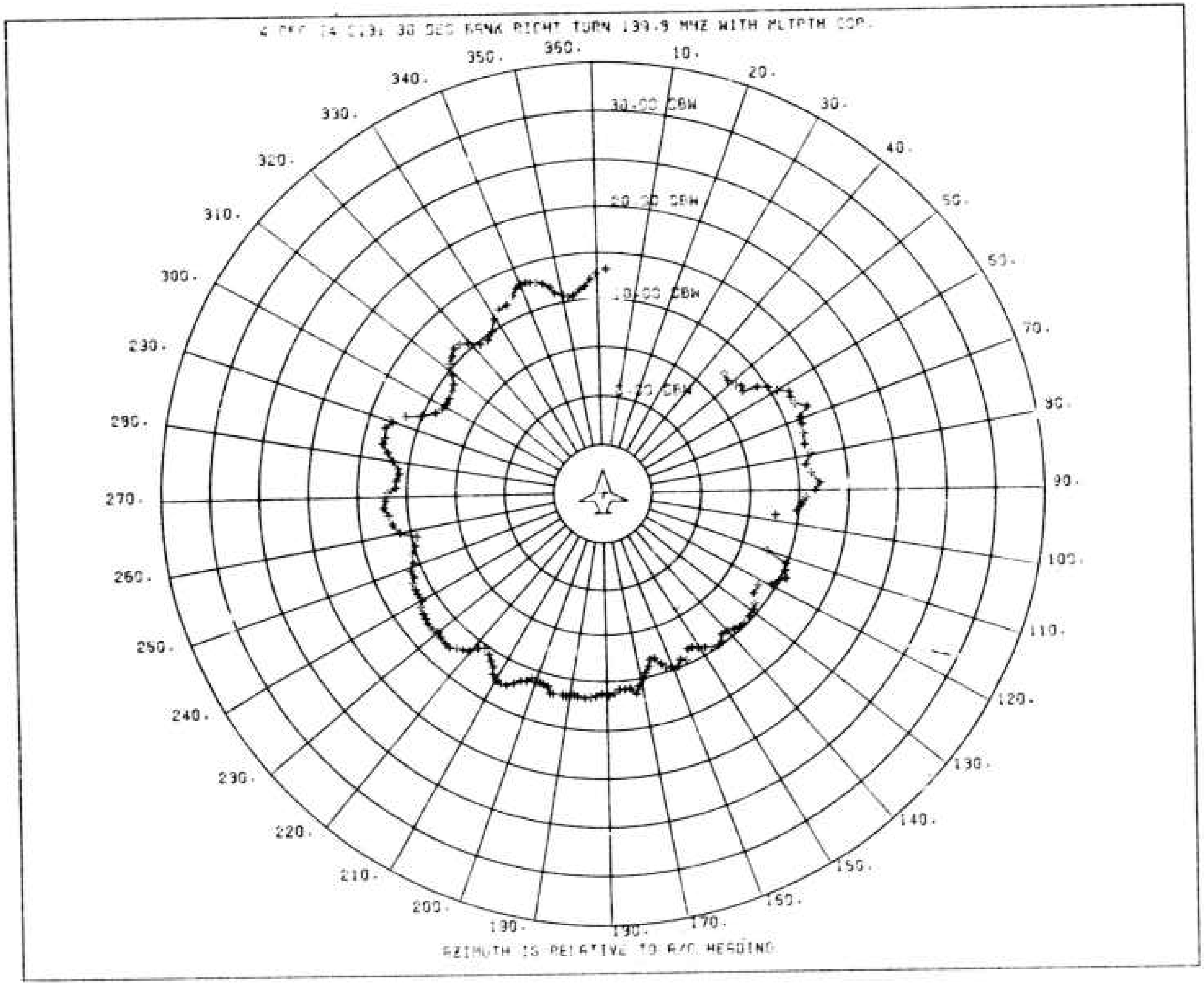

FIGURE 043 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

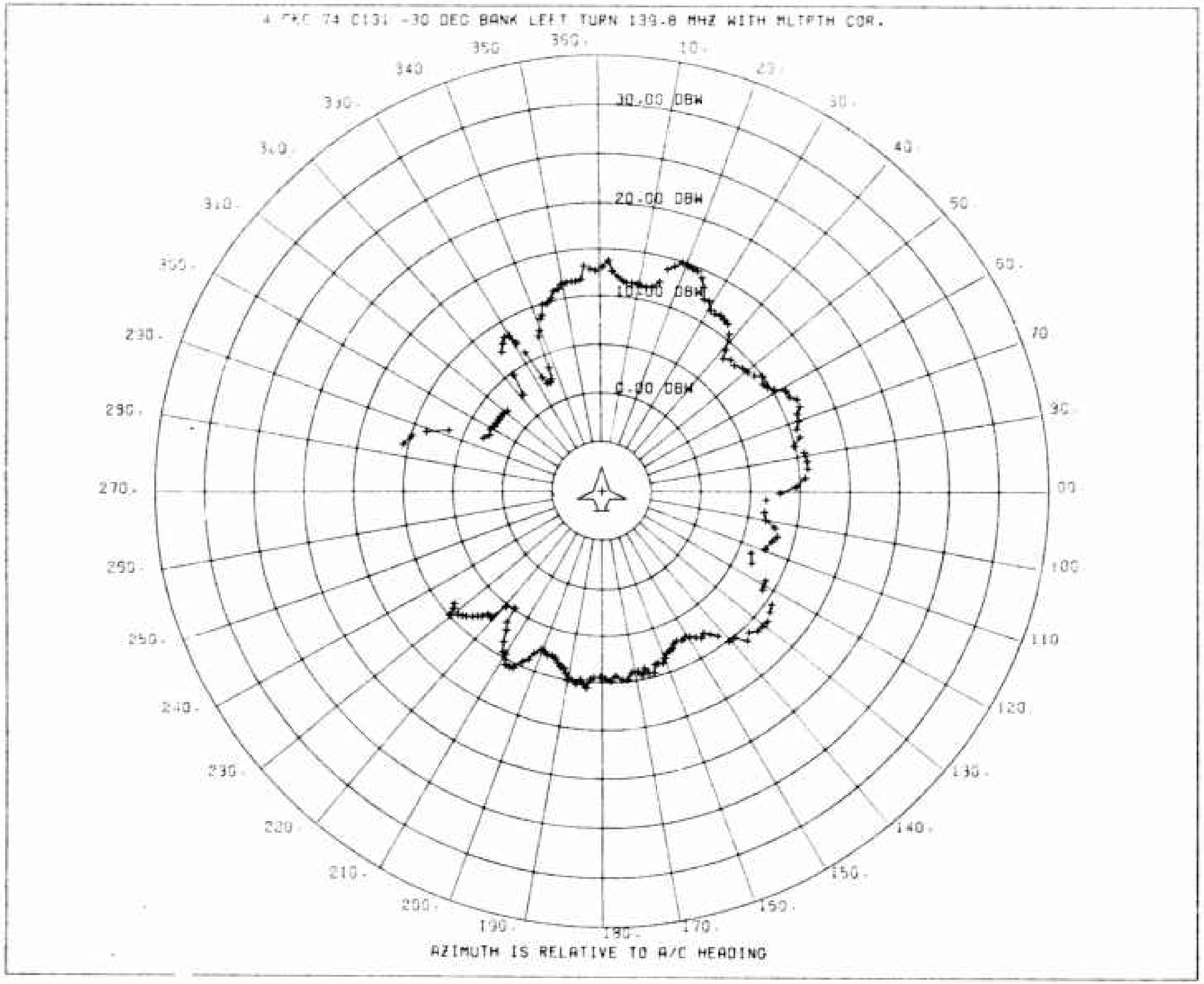

FIGURE D44 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

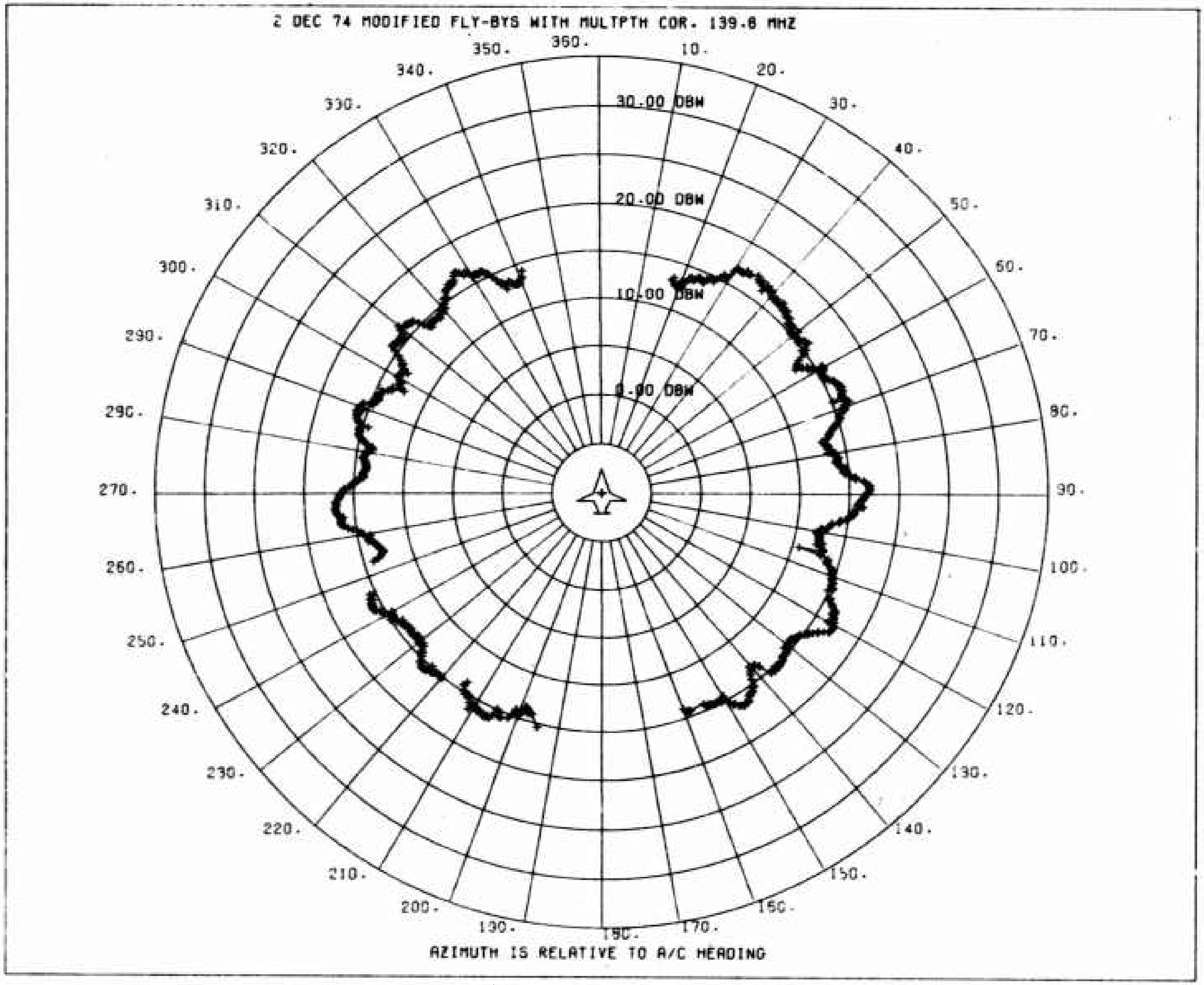

FIGURE D45 VHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

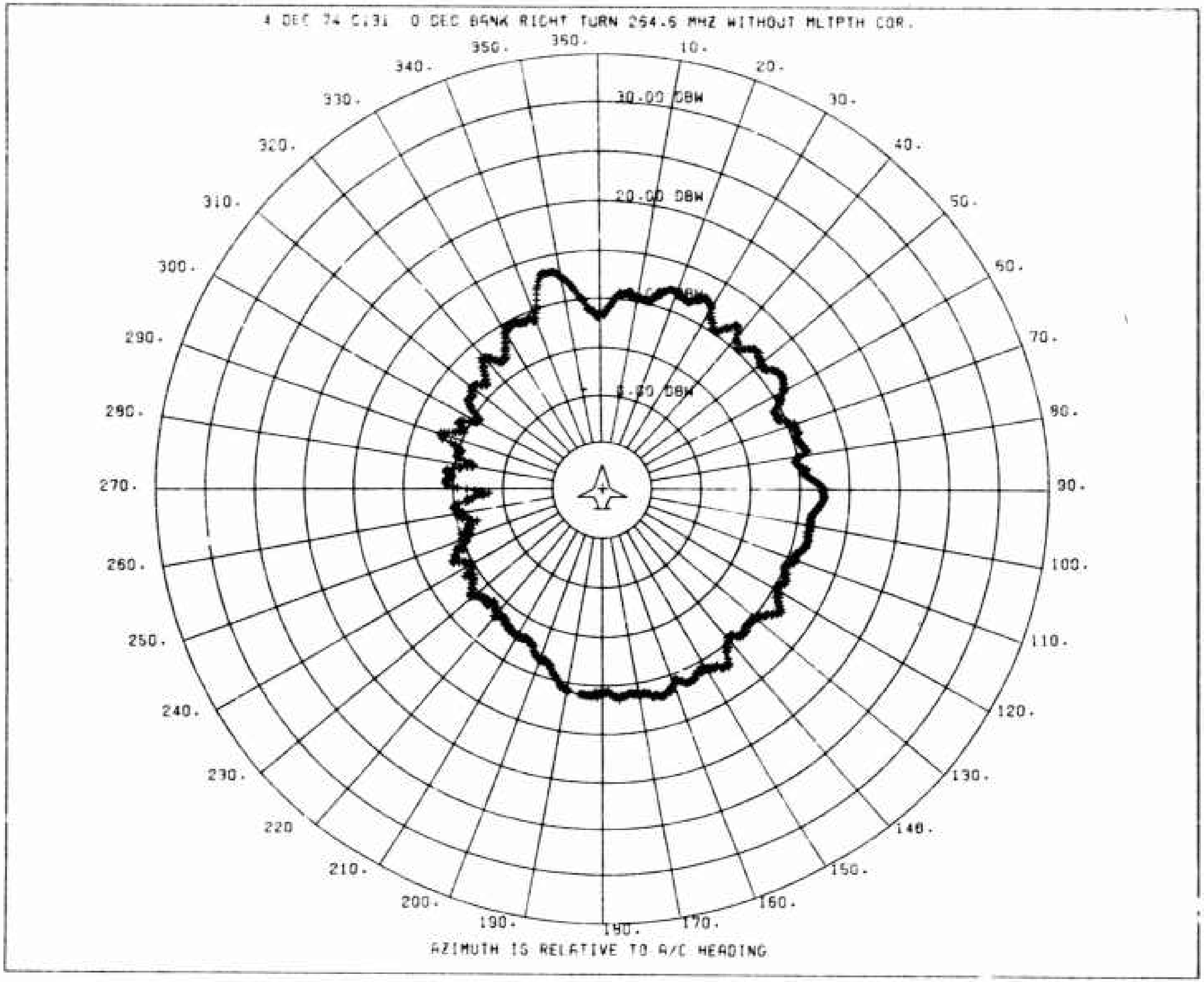

FIGURE D46 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

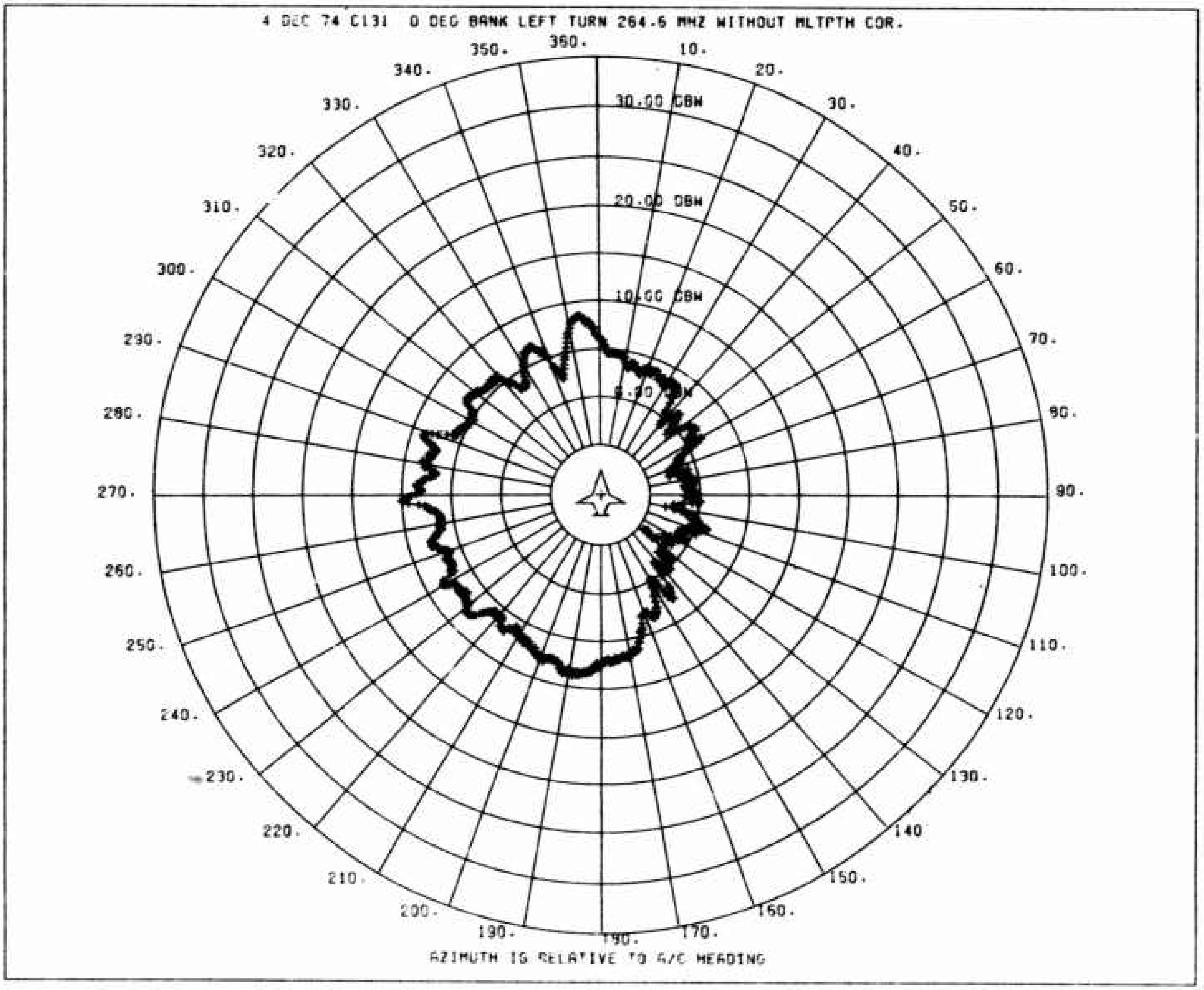

FIGURE D47 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

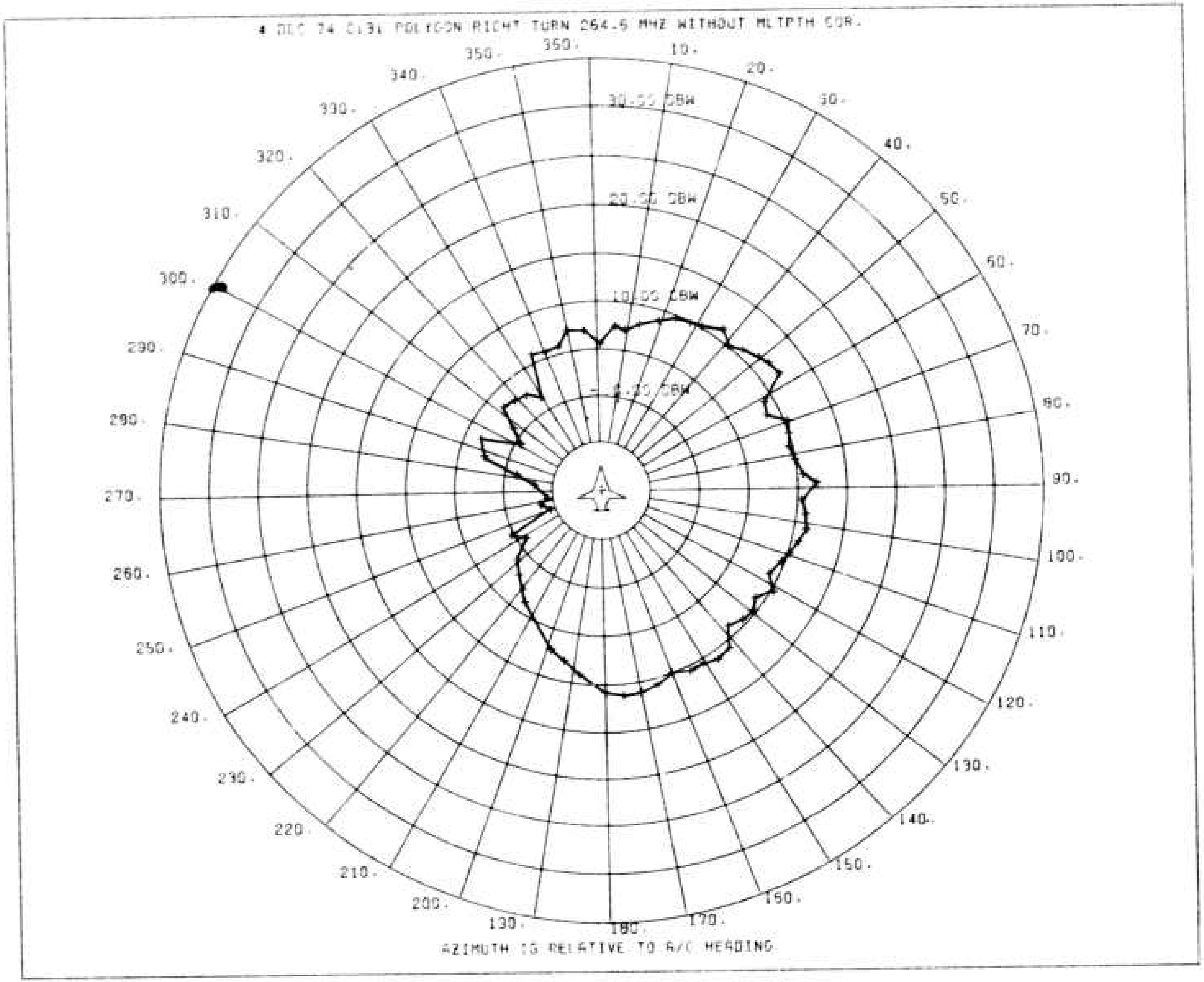

FIGURE D48 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

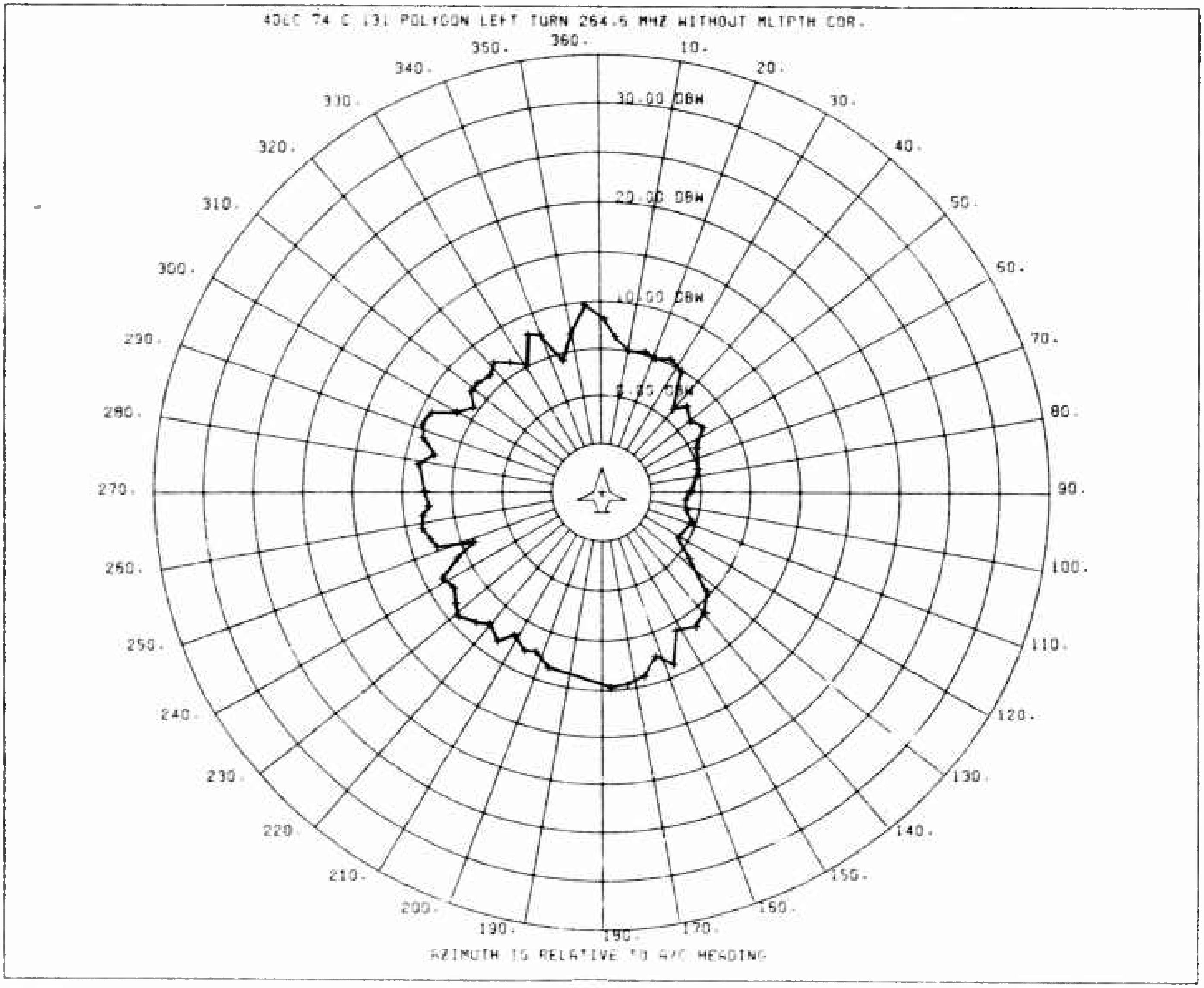

FIGURE D49 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

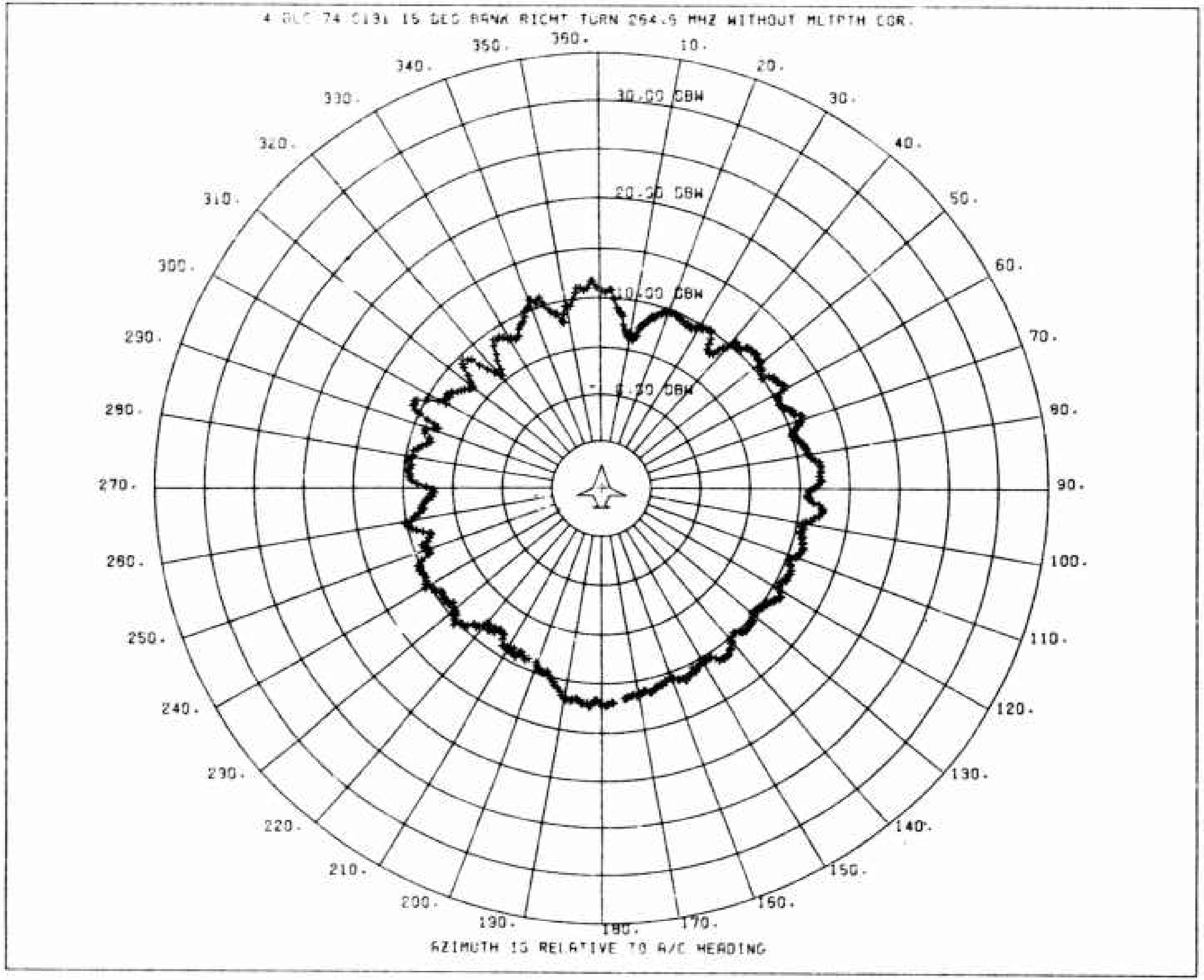

FIGURE D50 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

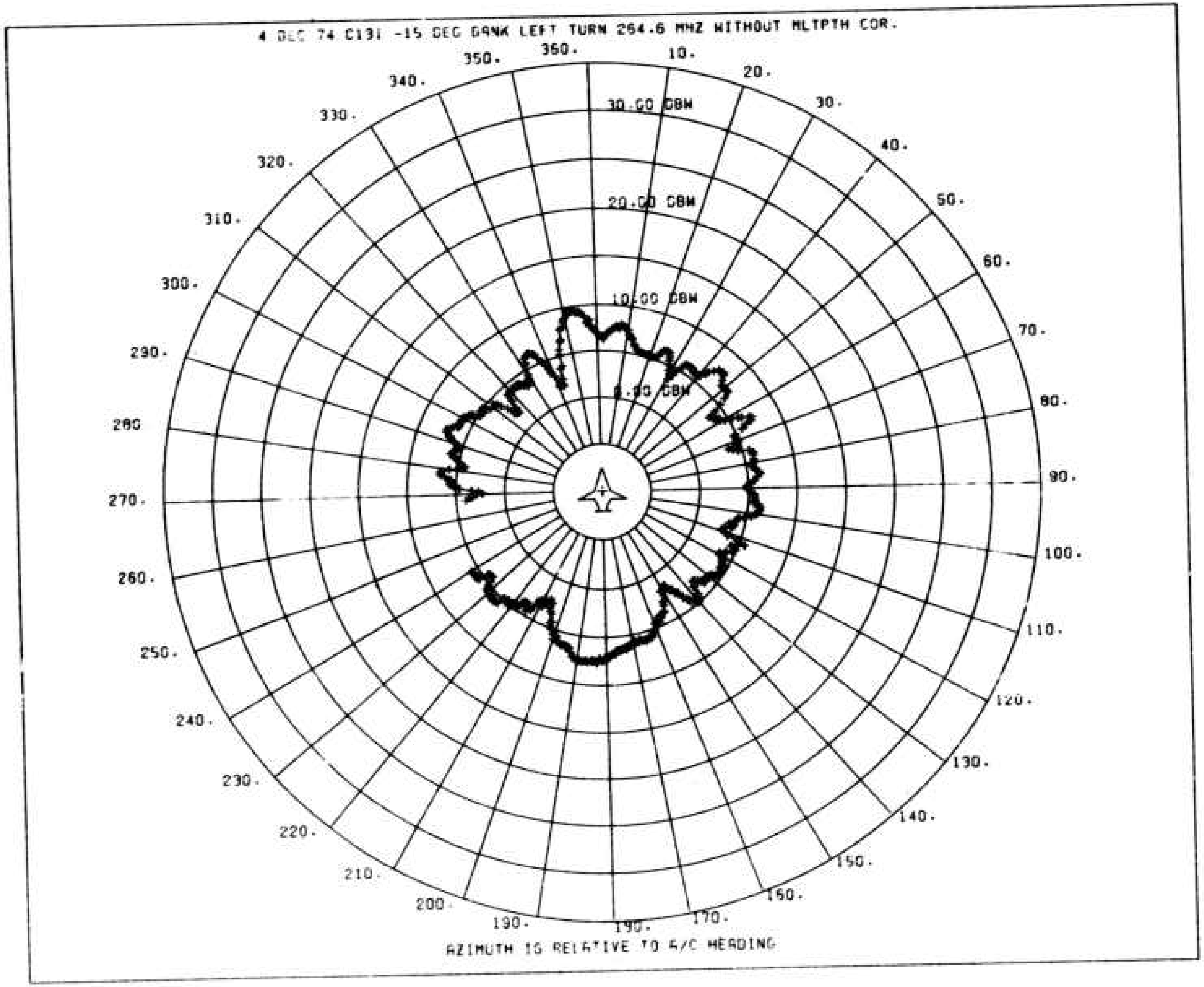

FIGURE 051 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

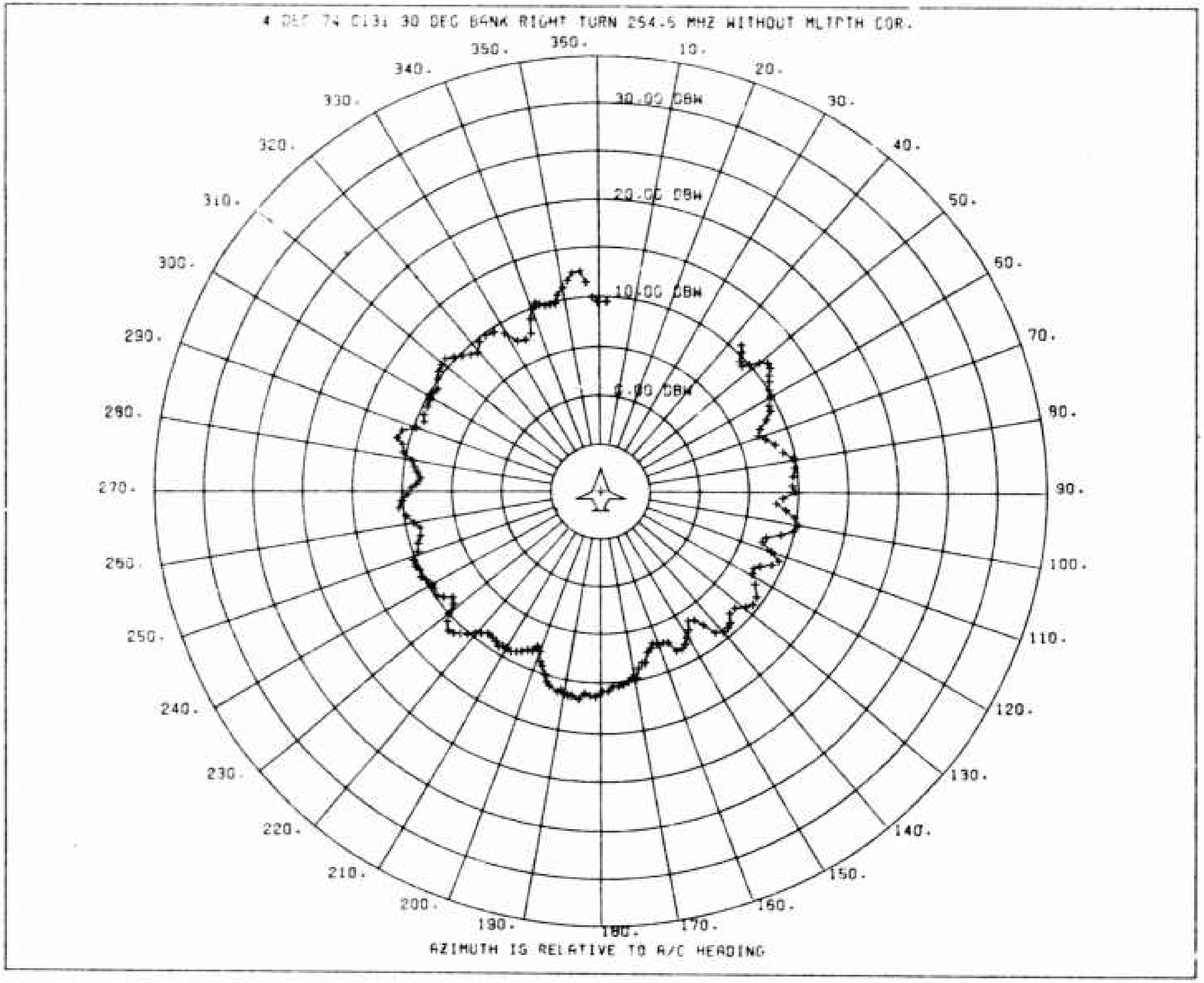

FIGURE D52 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

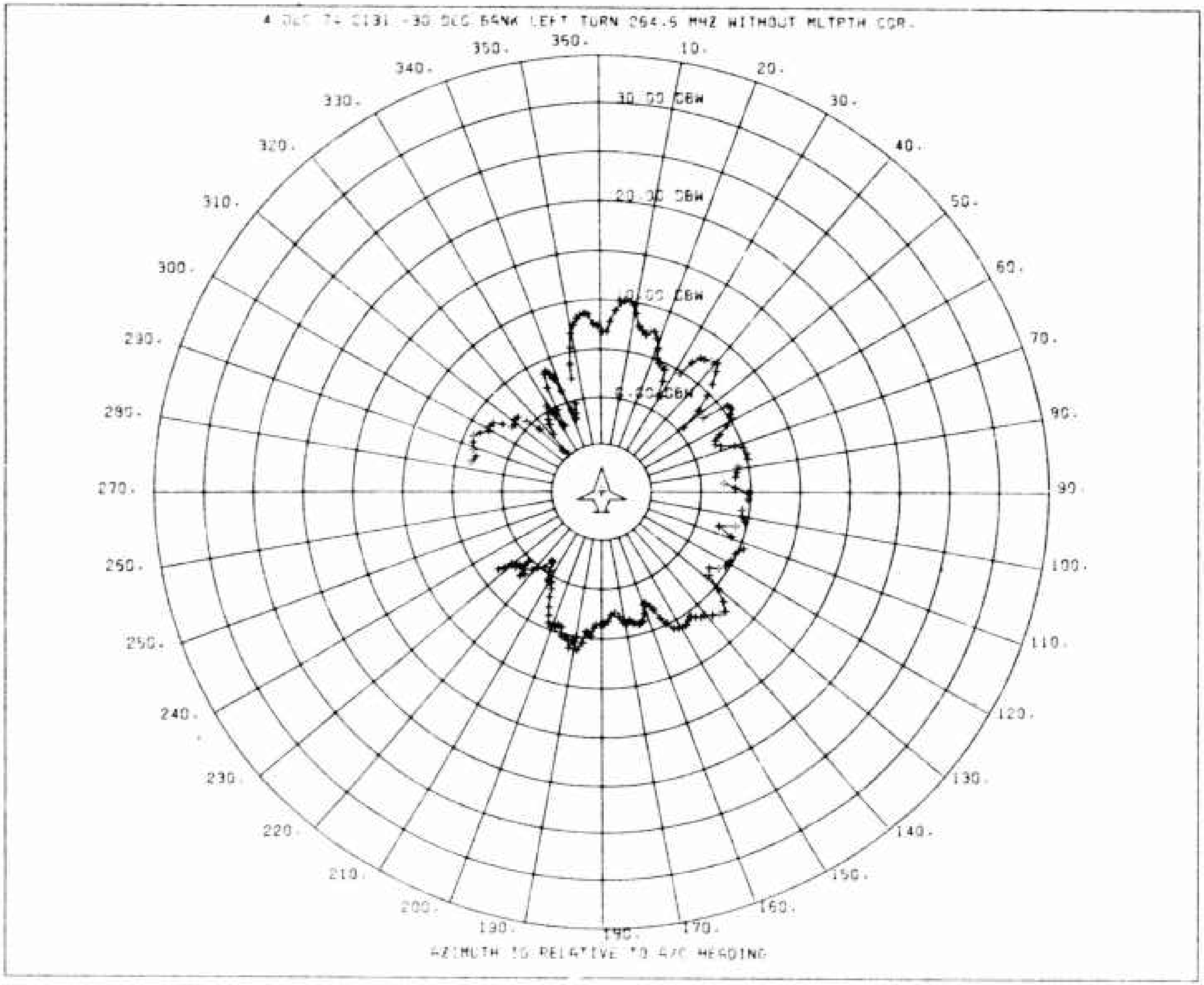

FIGURE D53 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

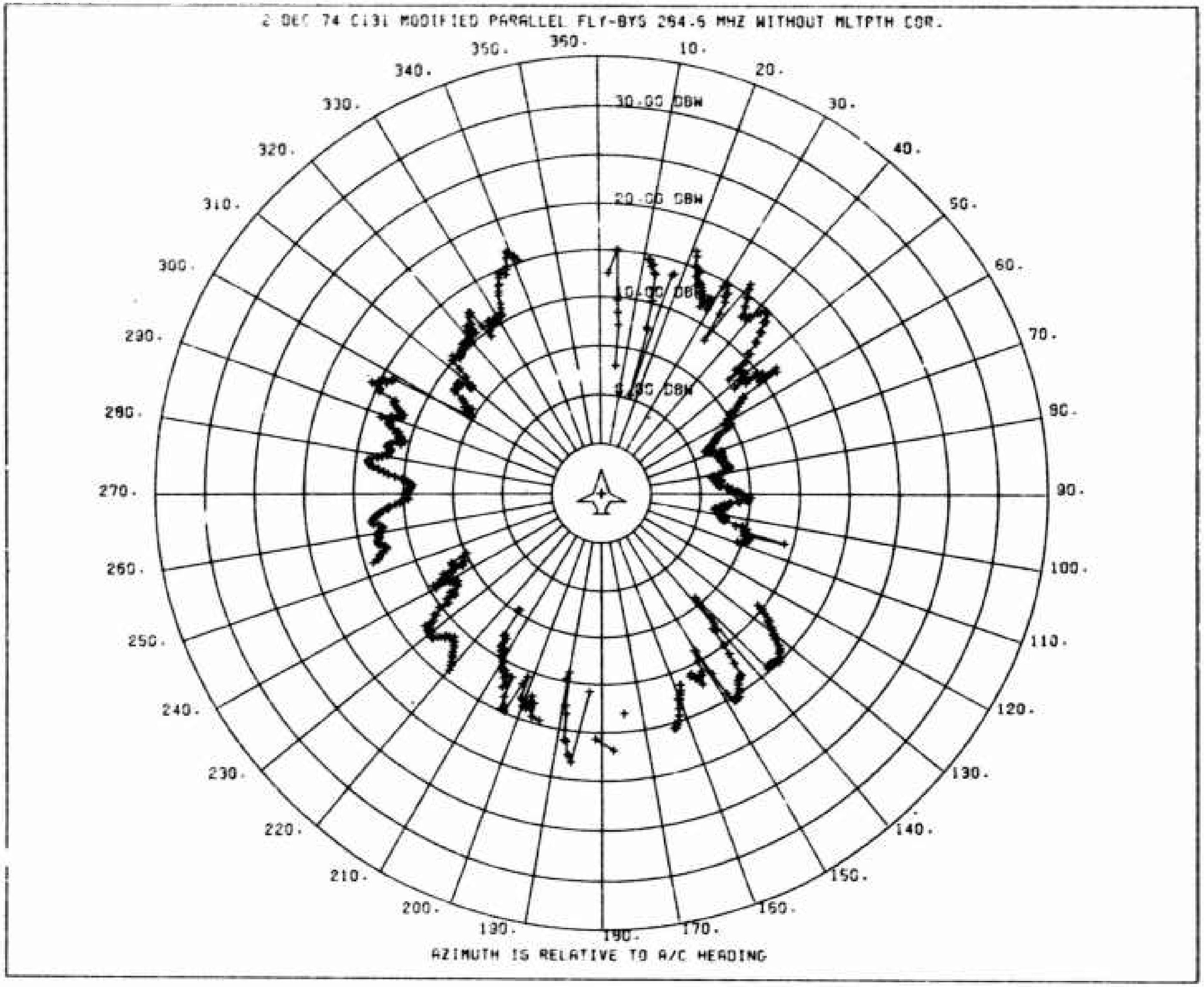

FIGURE D54 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

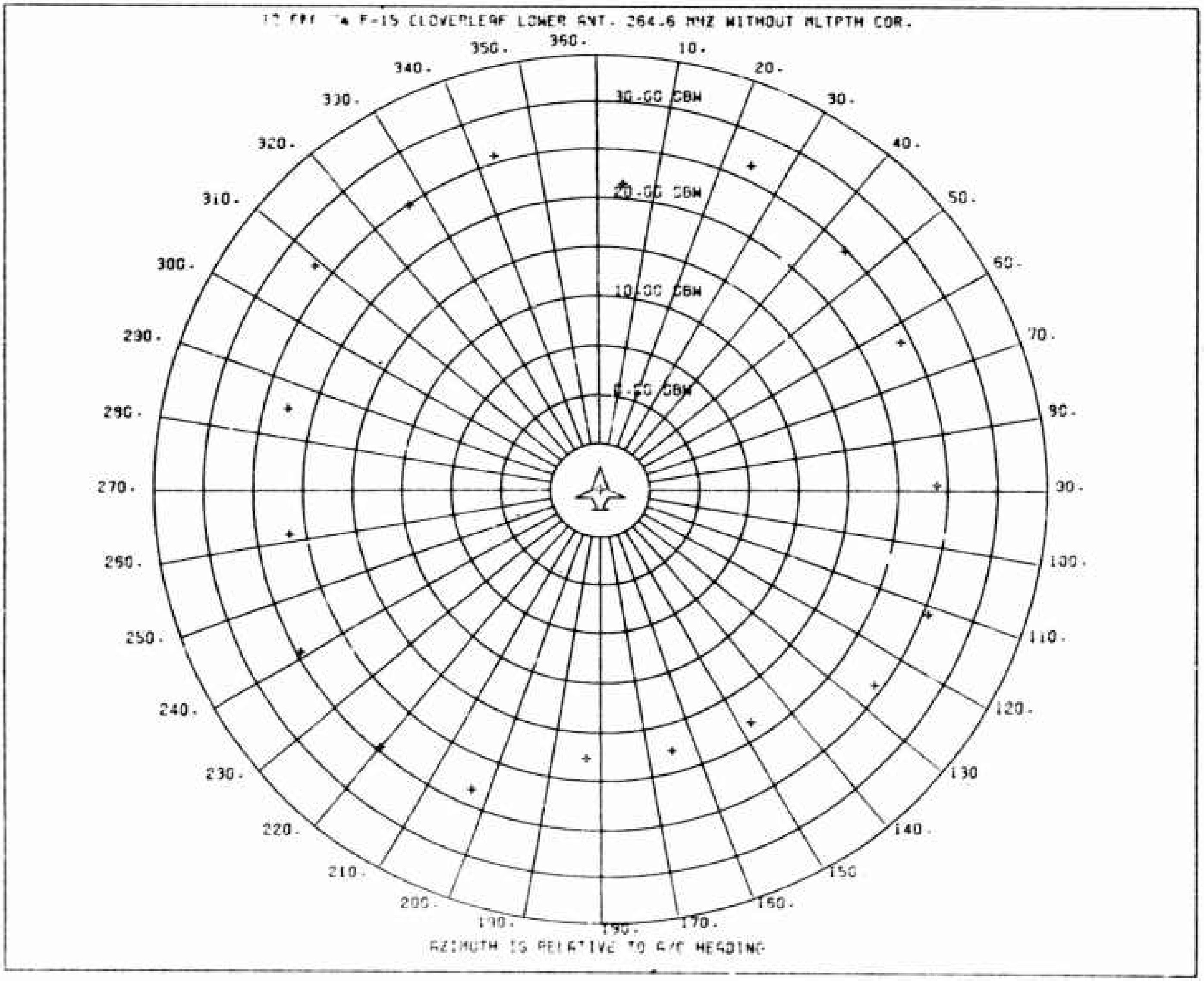

FIGURE D55 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

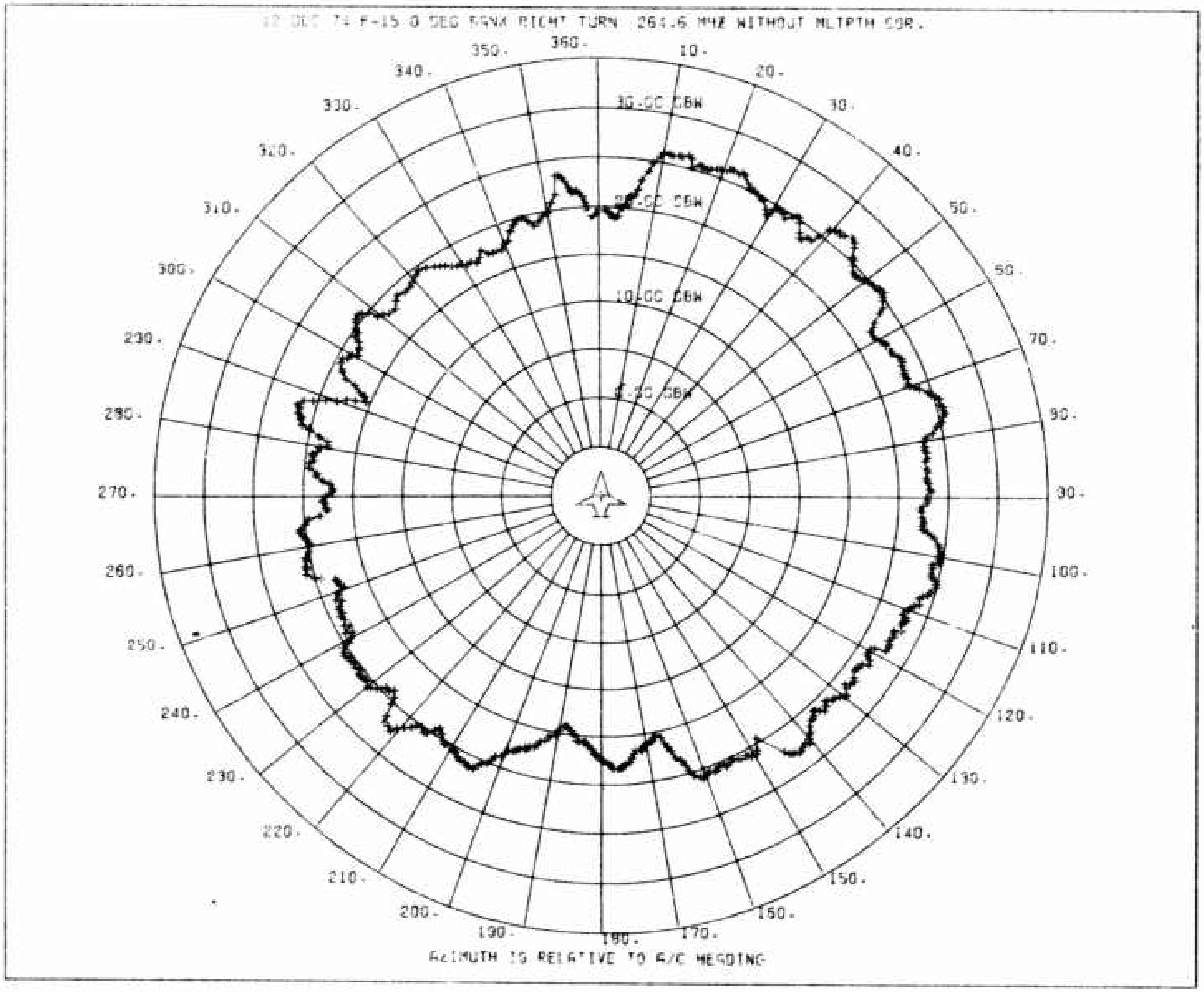

FIGURE 056 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

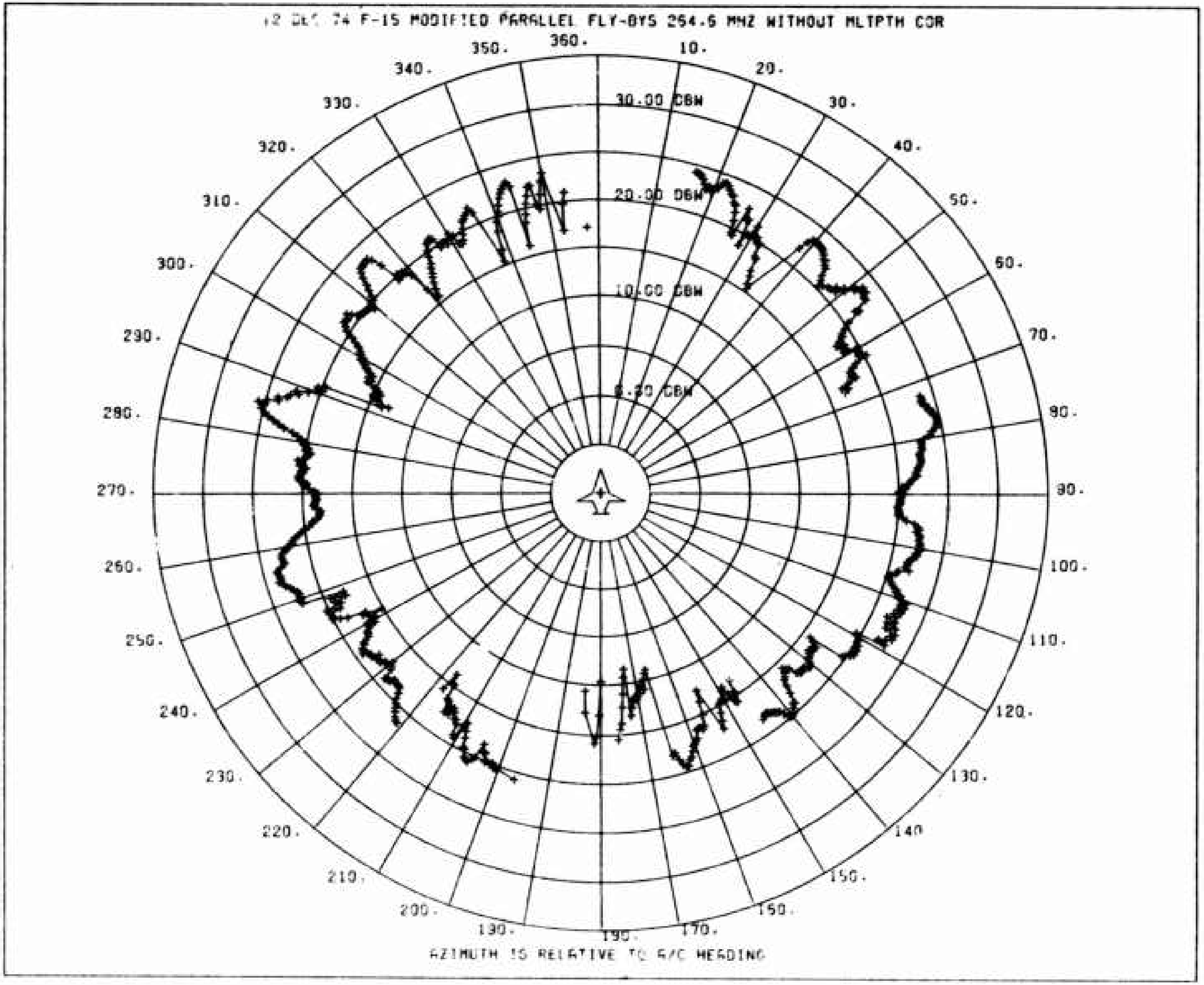

FIGURE D57 UHF ANTENNA PATTERNS WITHOUT MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

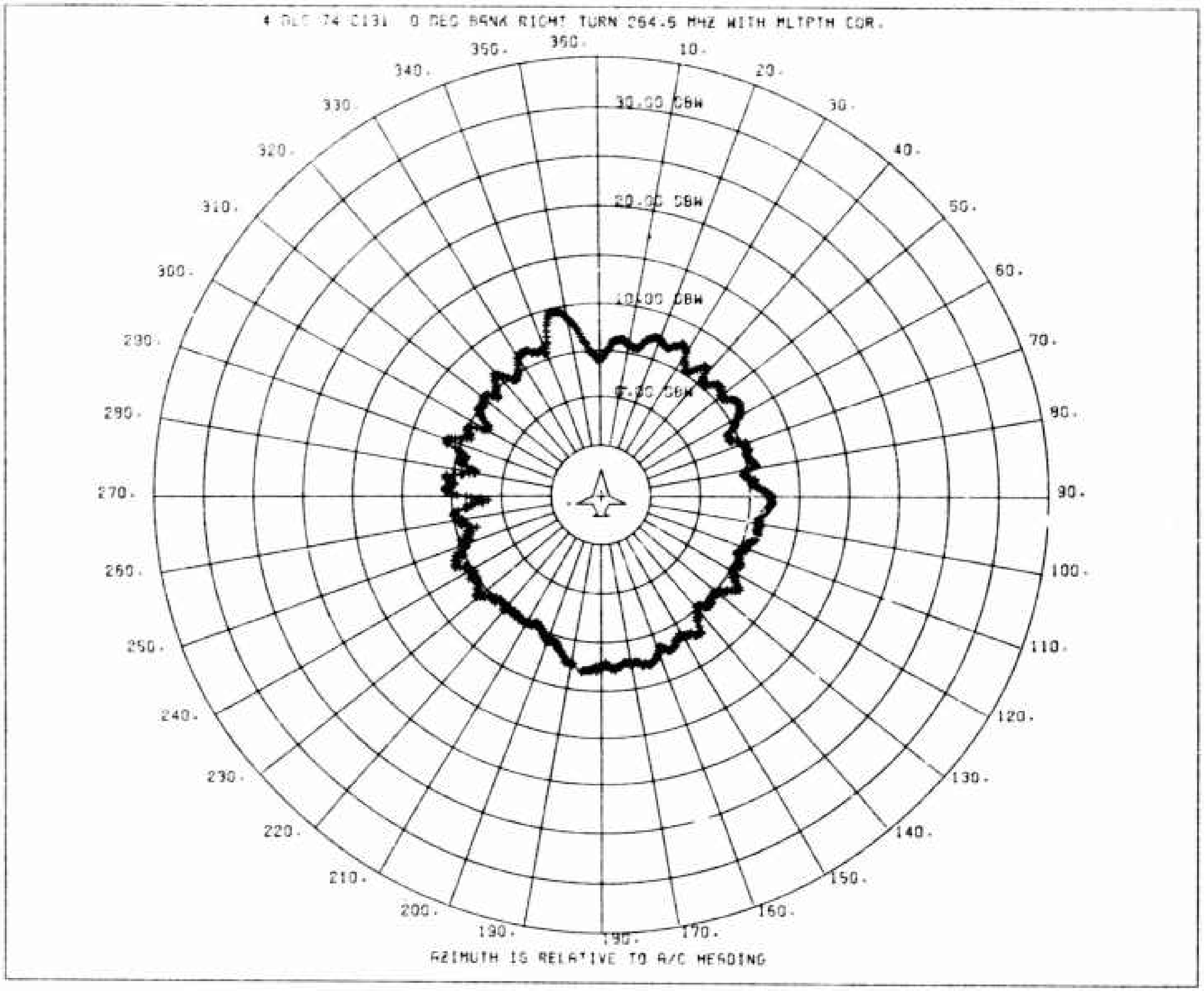

FIGURE D58 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

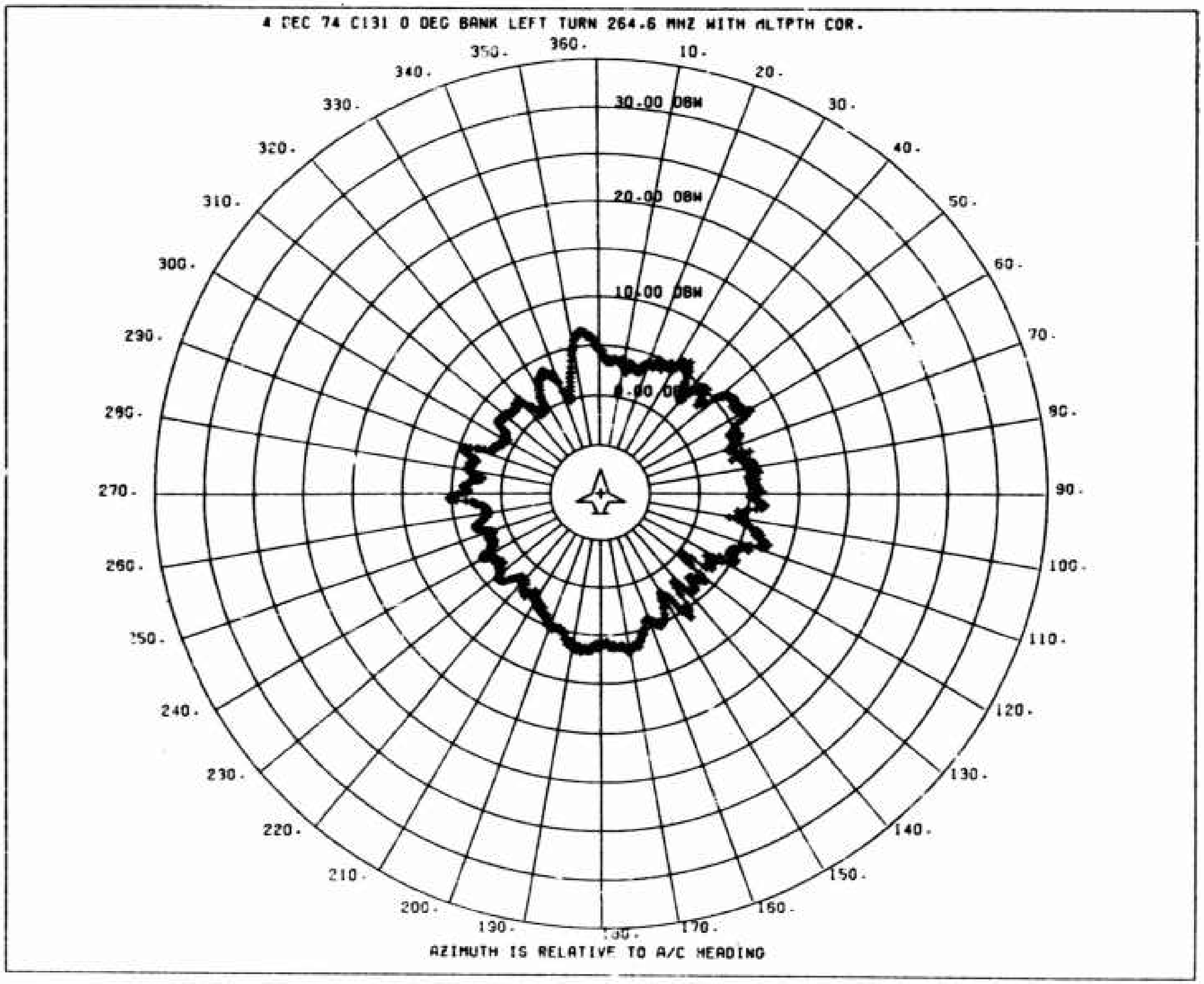

FIGURE D59 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

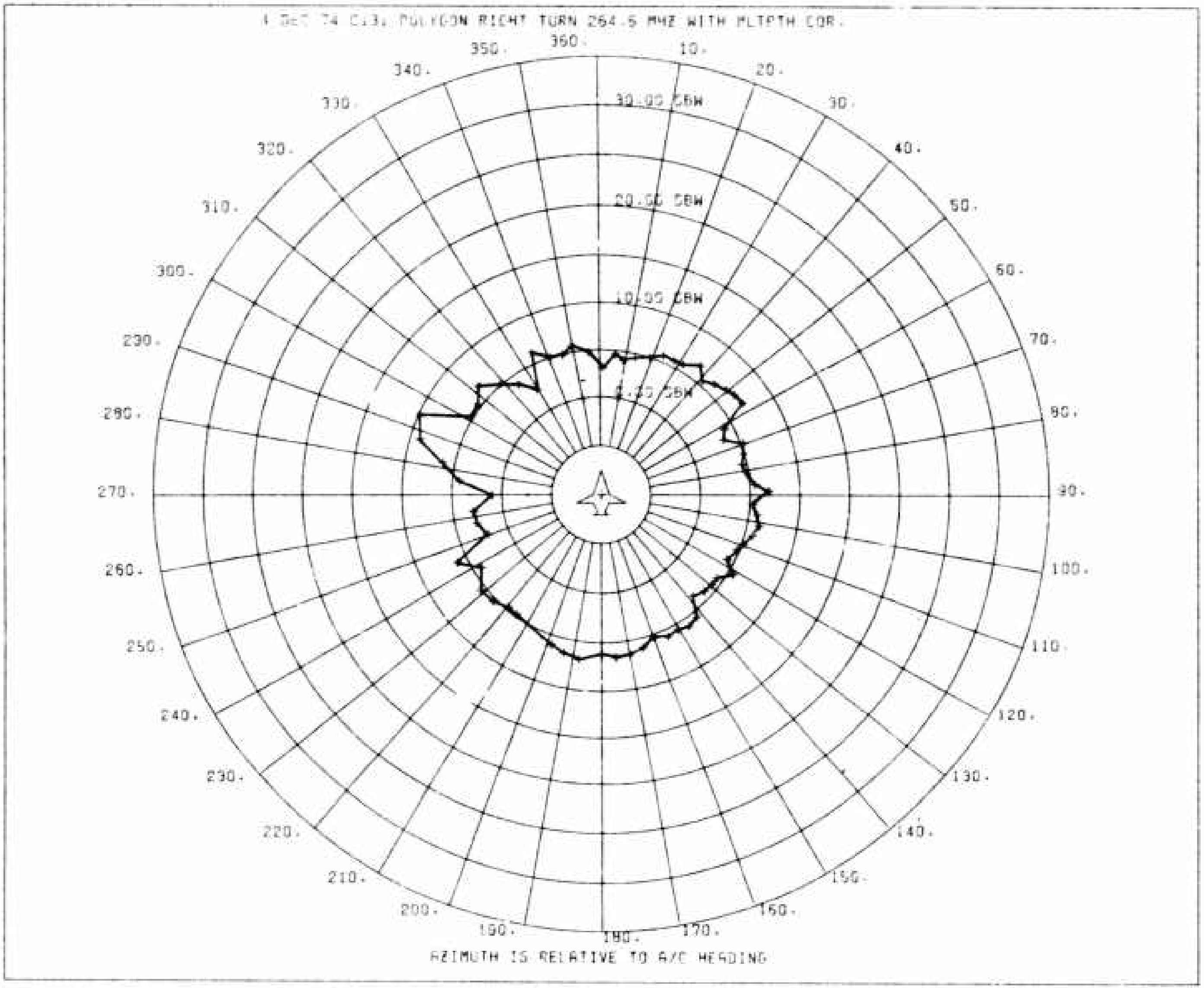

FIGURE D60 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

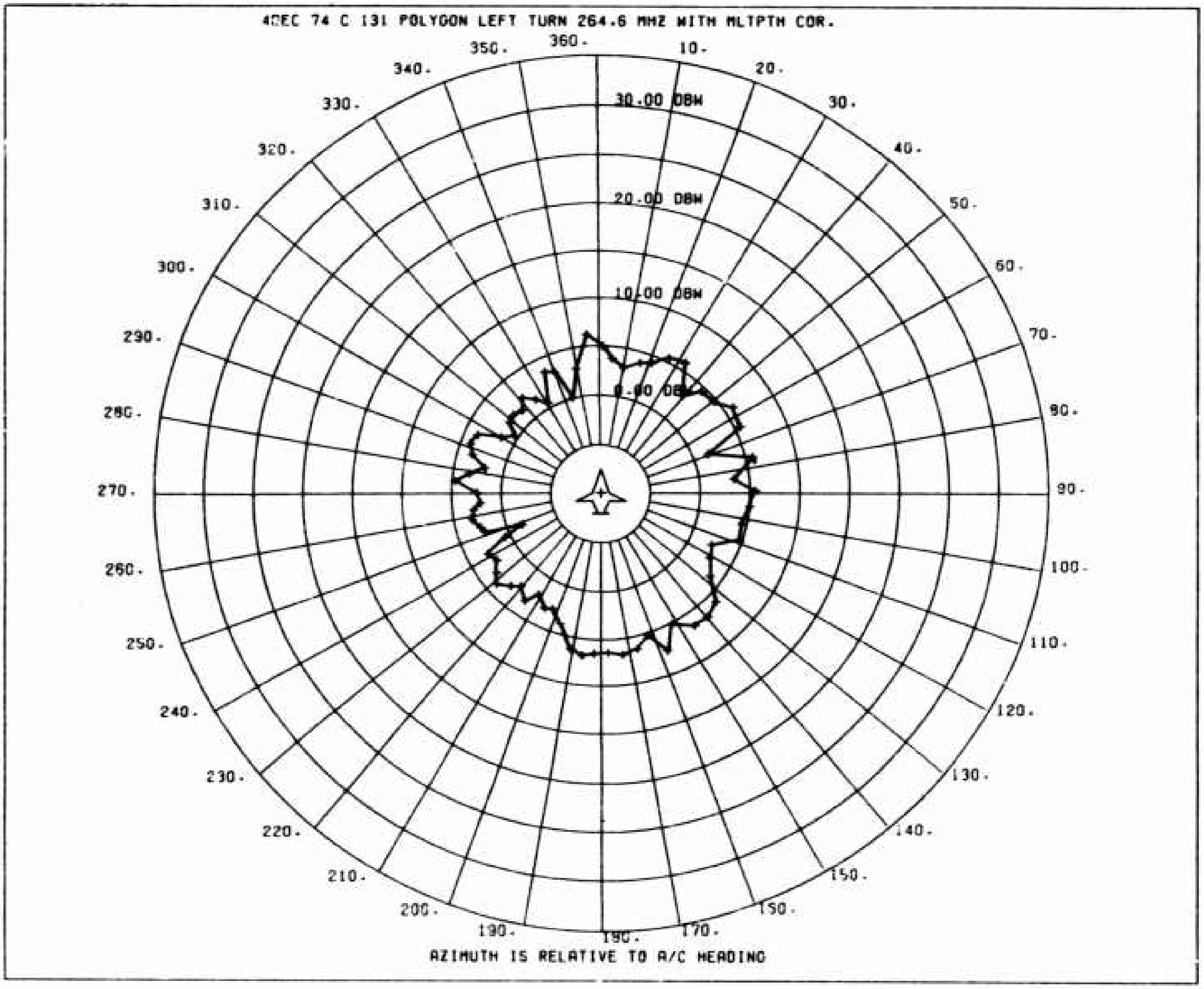

FIGURE D61 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

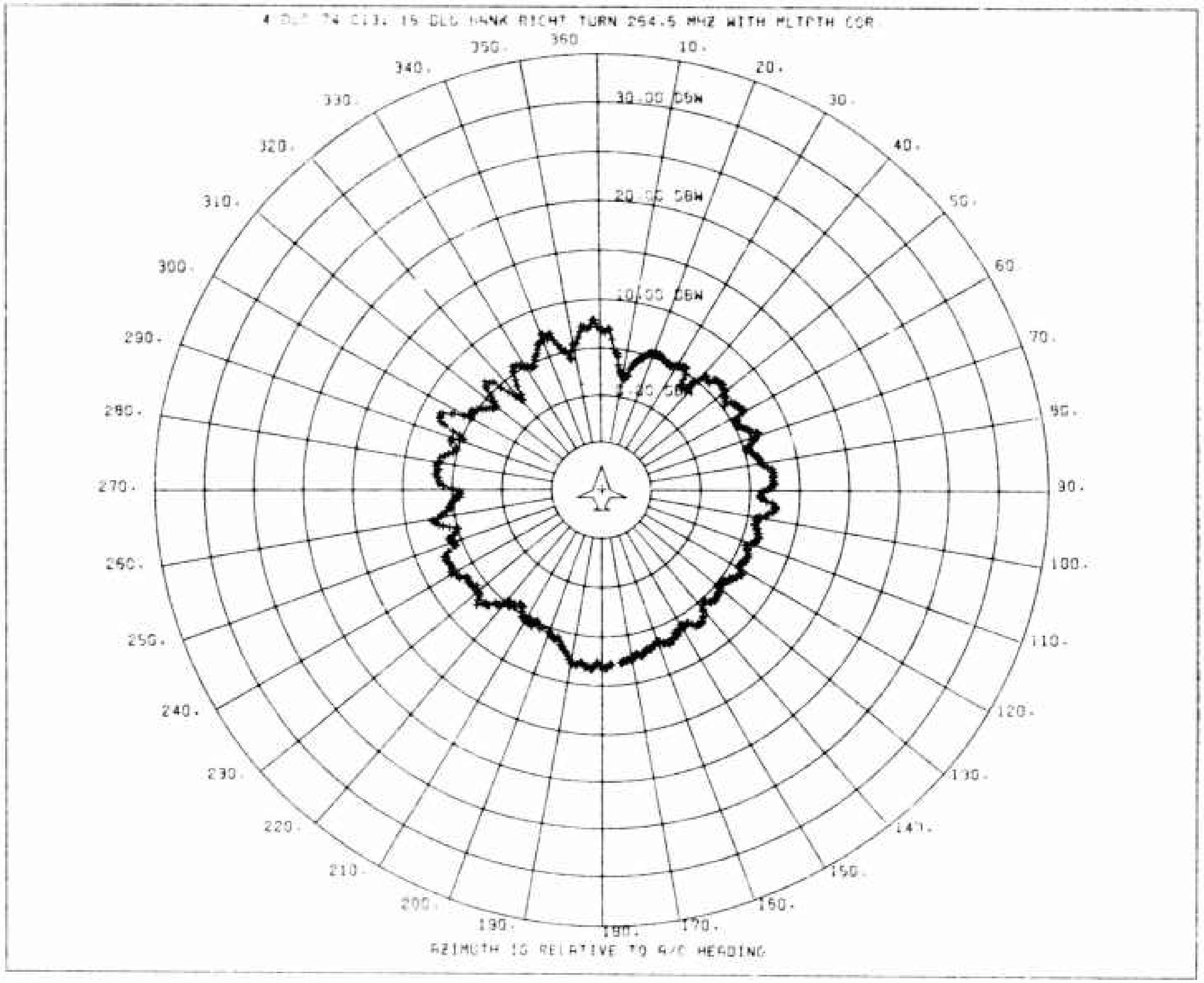

FIGURE D62 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

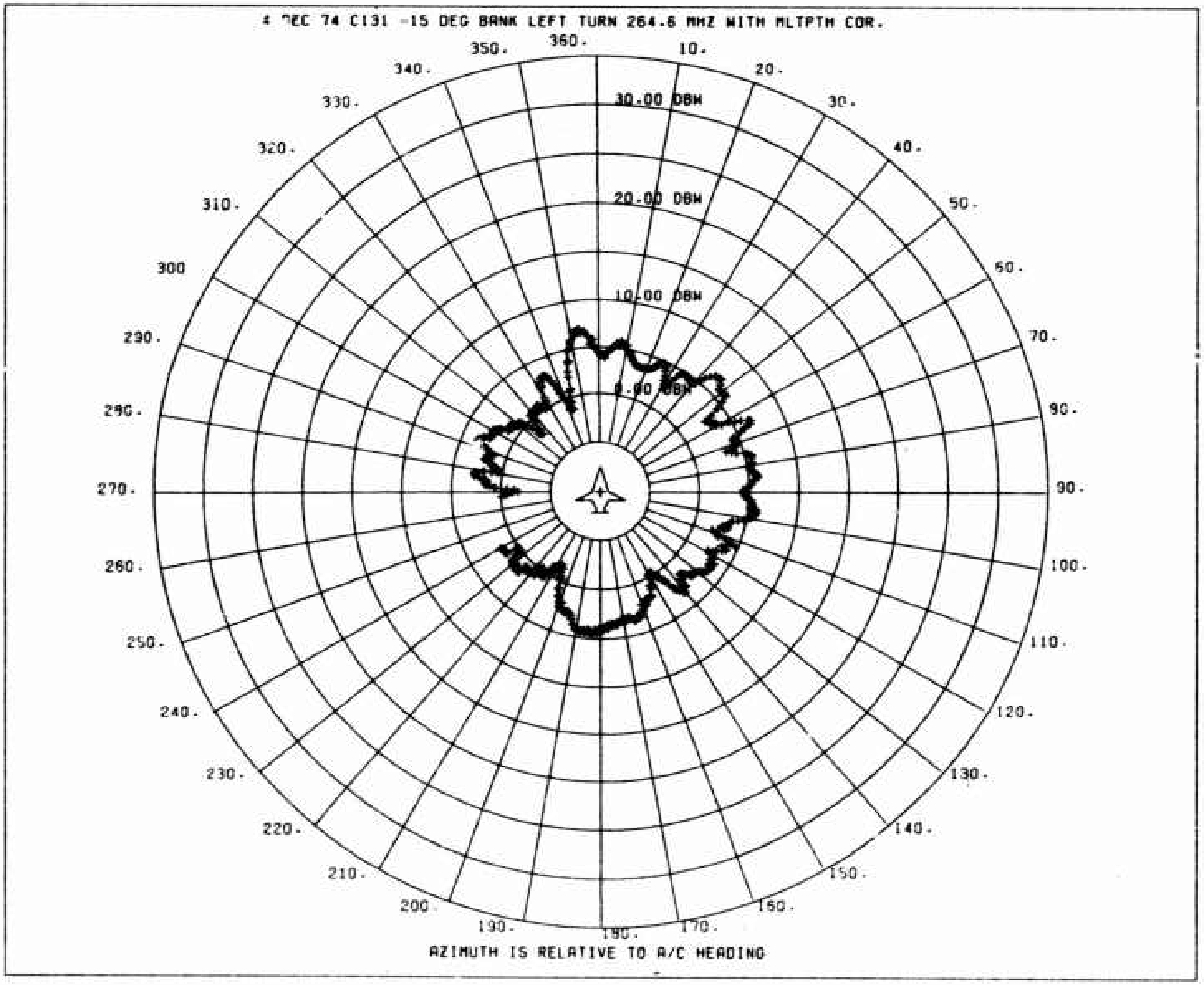

FIGURE D63 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

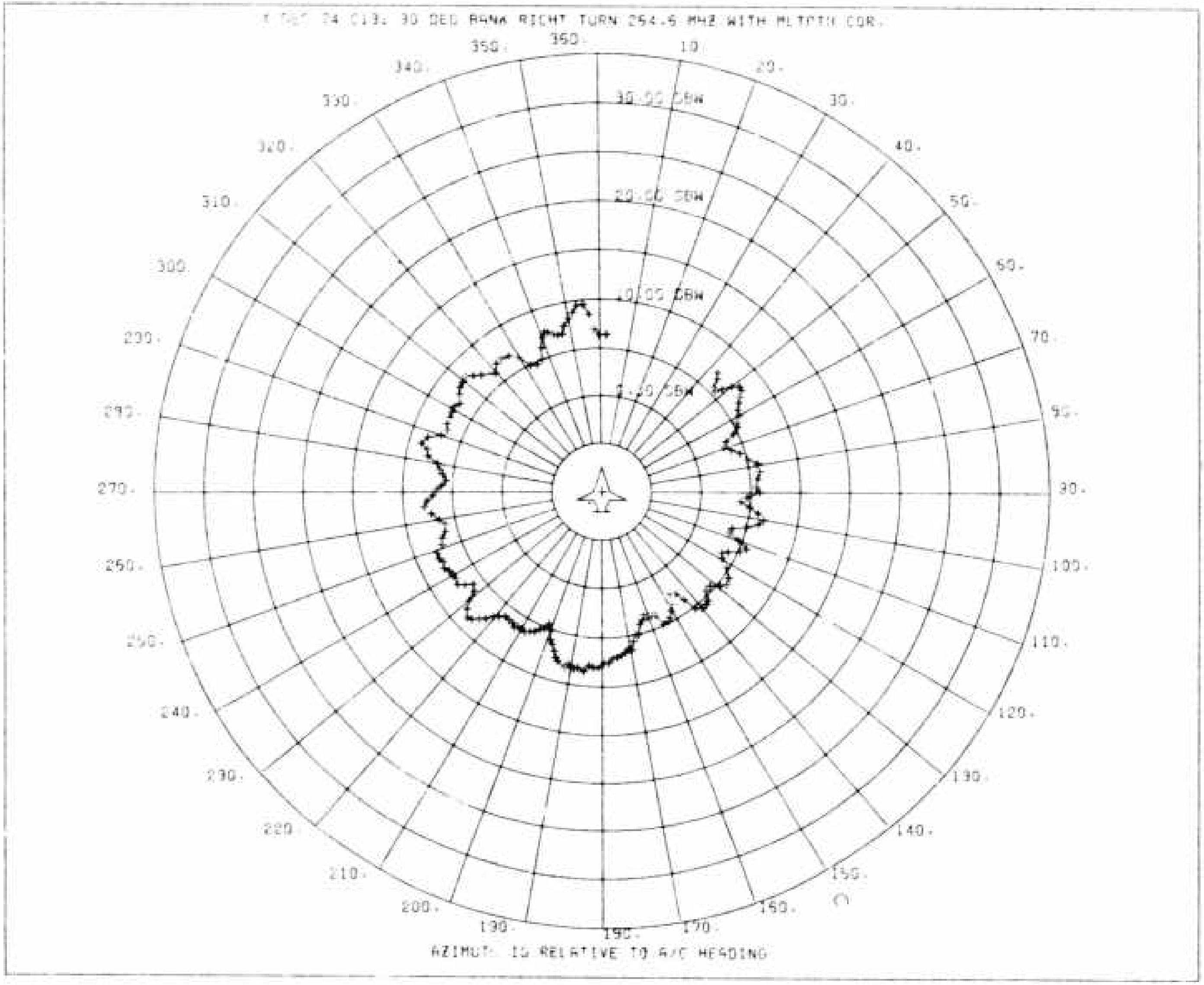

FIGURE D64 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

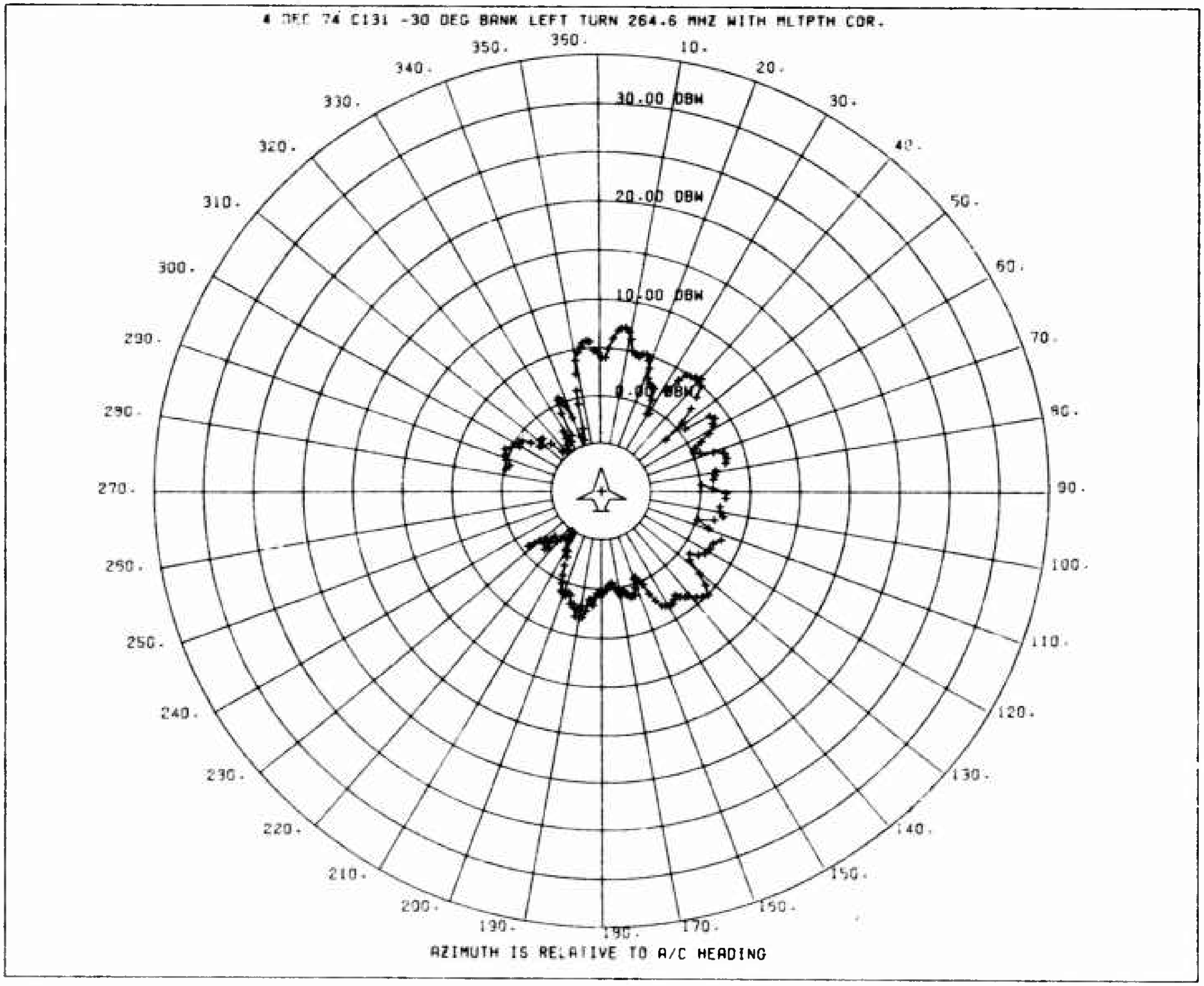

FIGURE 065 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

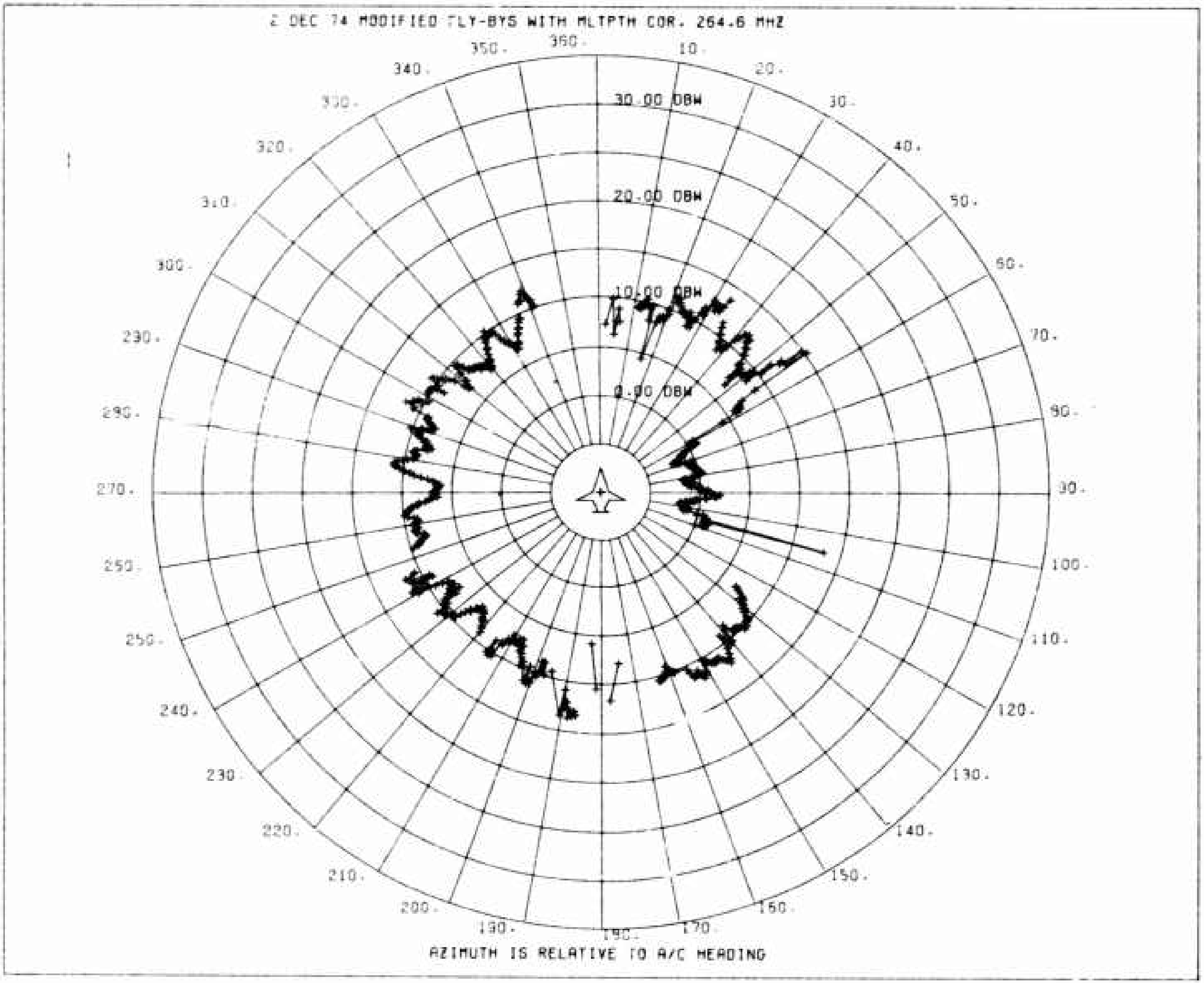

FIGURE 066 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

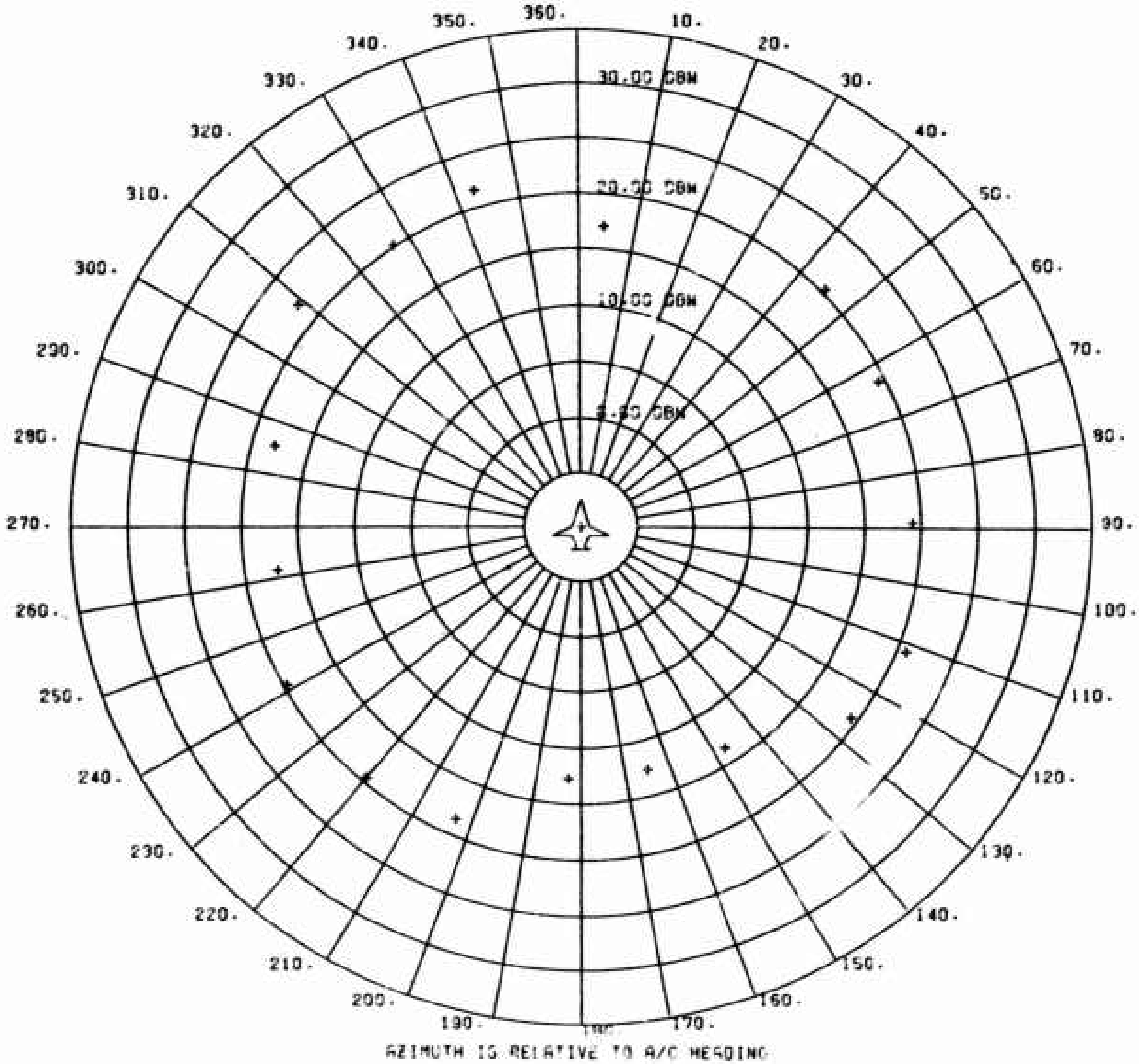

FIGURE D67 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

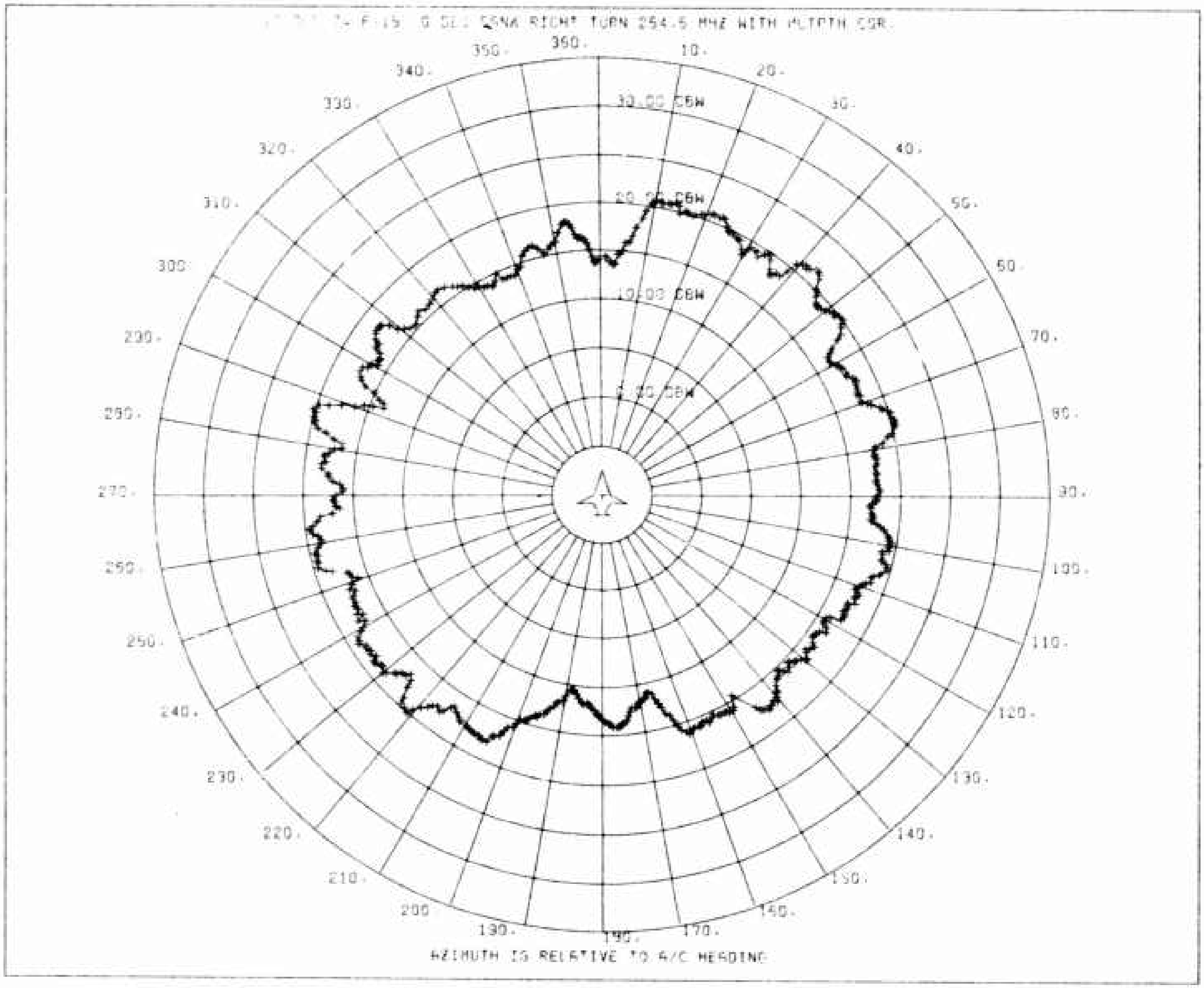

FIGURE D68 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

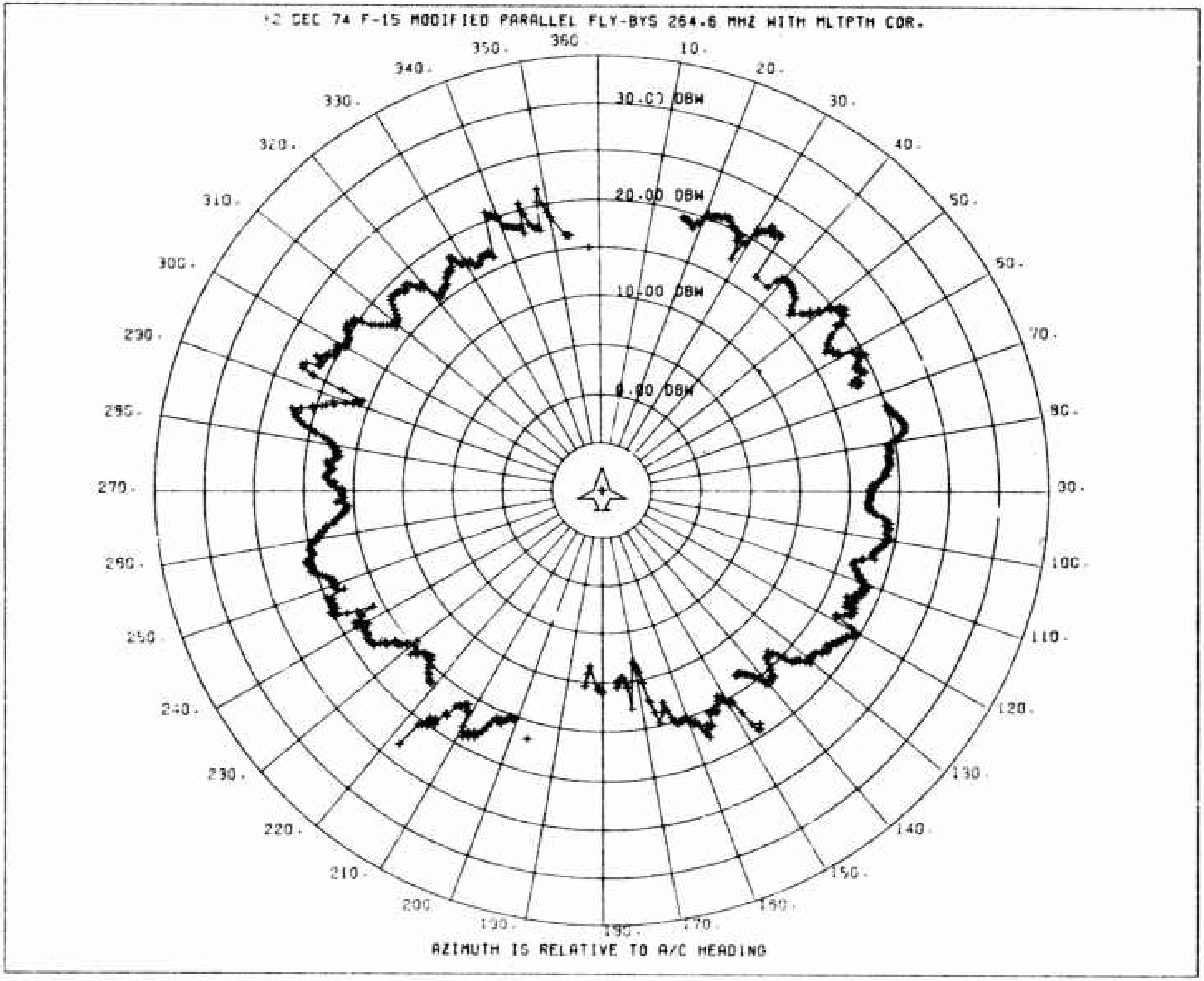

FIGURE D69 UHF ANTENNA PATTERNS WITH MULTIPATH CORRECTIONS (EDWARDS AFB TEST)

APPENDIX E

MULTIPATH RADIATION

TWO-PATH PROPAGATION CALCULATION

The theory of two-path propagation is thoroughly developed in most textbooks on electromagnetic wave propagation. This appendix was written to provide a condensed and simplified presentation on multipath radiation theory and to show the multipath prediction technique used by the computer programs documented in appendices B and C. Since a complete development of the theory is not presented in this report, the symbology used will follow that used by Reed and Russell (reference 5). This will allow the reference to be easily used if a more detailed explanation of the theory is required. This section will include four basic concepts which make up the theory of multipath radiation predictions. They are as follows: (a) earth gain factor ($g(\theta)$), (b) divergence factor (D), (c) reflection coefficient (R) of the reflecting surface, and (e) the geometric relationship between the receiving antenna, the transmitting antenna, and the reflecting surface.

EARTH GAIN FACTOR

The earth gain factor $g(\theta)$ is the ratio of the resultant vector (sum of the direct and reflected signal) to the direct signal.

$$g(\theta) = \frac{\mathit{E}_R}{\mathit{E}_O} \tag{1}$$

E_R = resultant signal*

E_O = direct signal

The relationship of the two vectors is shown in figure E1.

*Note: Vectors are represented by italic characters in this report.

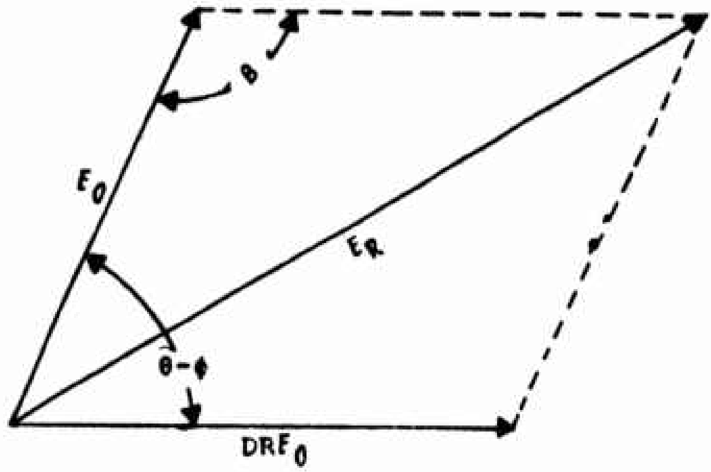

Figure E1 Resultant of Direct and Reflected Vector

Where DRE_O is the reflected signal, D is the divergence factor, R is the reflection coefficient ($R = |R|$), θ is the phase change of the reflected signal due to the difference in path length, and $-\phi$ is the phase change due to the reflection.

By the law of cosines

$$E_R^2 = E_O^2 + (DRE_O)^2 - 2E_O DRE_O \cos(\beta) \tag{2}$$

since

$$\beta = 180 - (\theta - \phi)$$

and

$$\cos(\beta) = \cos(180 - (\theta - \phi)) = -\cos(\theta - \phi) \tag{3}$$

then

$$E_R = E_O \sqrt{1 + (DR)^2 + 2DR\cos(\theta - \phi)} \tag{4}$$

therefore, the earth gain factor is equal to:

$$g(\theta) = \frac{E_R}{E_O} = \sqrt{1 + (DR)^2 + 2DR\cos(\theta - \phi)} \tag{5}$$

This is the predicted gain due to multipath signals, which in db is equal to:

$$g(\theta)_{db} = 10 \log g(\theta) \tag{6}$$

DIVERGENCE FACTOR

The divergence factor (D) is the ratio of the spread of a beam reflected off a plane surface to the spread of a beam reflected off a spherical surface. When a diverging beam is reflected off a plane surface, the direction of the beam is altered but the rate of divergence is left unchanged (figure E2). For example, a direct beam and a reflected beam which travel the same distance, as measured along the beam's axis, will diverge to the same size.

This is not true when the reflecting surface is a sphere. Since the angle of incidence is equal to the angle of reflection, a curved surface will cause an increase in the rate of divergence of a reflected beam (figure E3).

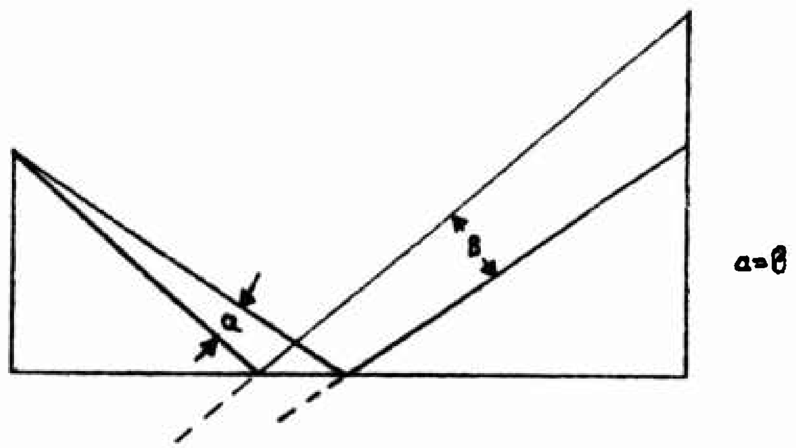

Figure E2 Plane Surface Divergence

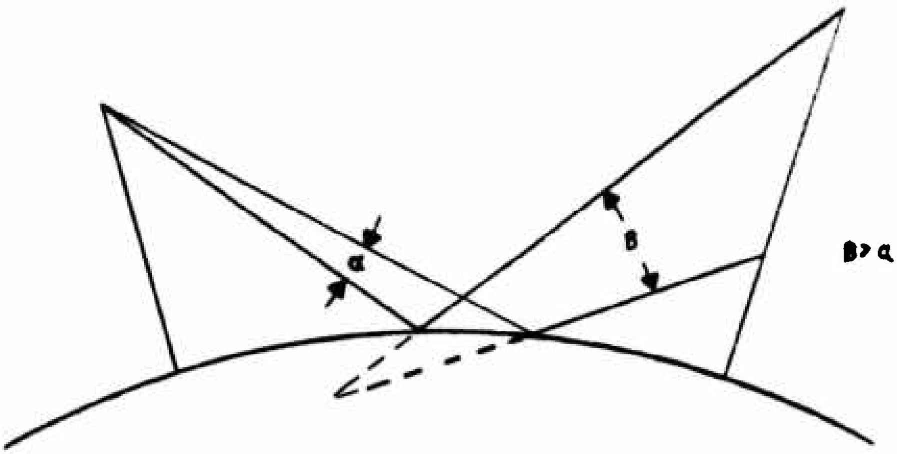

Figure E3 Curved Surface Divergence

A complete development of the divergence equations can be found in Reed and Russell (reference 5). The equations are developed based on comparing the cross sectional areas of the diverging beams. The ratio of the areas will reduce to (figure E4):

$$D = \frac{1}{\sqrt{1 + \dfrac{2r_1 r_2}{rd \tan \psi}}} \tag{7}$$

When $d \ll r$ then $r_1 \approx h_1'/\sin \psi$; $r_2 \approx h_2'/\sin \psi$ and for small grazing angles $\sin \psi \approx \tan \psi$ which yields

$$D \approx \frac{1}{\sqrt{1 + \dfrac{2h_1' h_2'}{rd \tan^3 \psi}}} \tag{8}$$

The final usable equation is obtained by the approximation

$$\tan \psi \approx \frac{h_1'}{5280d_1} \approx \frac{h_2'}{5280d_2} \tag{9}$$

and by applying 4/3 earth radius to eliminate the atmospheric refraction ($r \approx 5280$ miles), expressing h in feet, and d in statute miles. This reduces the divergence equation to

$$D \approx \left[1 + \frac{2d_1 d_2{}^2}{dh_2'} \right]^{-\frac{1}{2}} \tag{10}$$

Therefore, this equation can be used, for small grazing angles, to predict the approximate reduction in energy of a signal reflected off a spherical surface.

REFLECTION COEFFICIENT

The derivation of the reflection coefficient (R) is more complex than the divergence factor and a thorough discussion will not be attempted in this report. Rather, the basic equations will be presented and if a more detailed explanation is required, Reed and Russell may be referenced.

The reflection coefficient (R) is the ratio of the reflected ray (E_r) to the incident ray (E_i) and is a complex vector. It can be shown for a vertically polarized ray this ratio is equal to

$$R_v = \frac{E_r}{E_i} = \frac{n^2 \sin \psi - \sqrt{n^2 - \cos^2 \psi}}{n^2 \sin \psi + \sqrt{n^2 - \cos^2 \psi}} = |R_v| e^{j\phi_v} \tag{11}$$

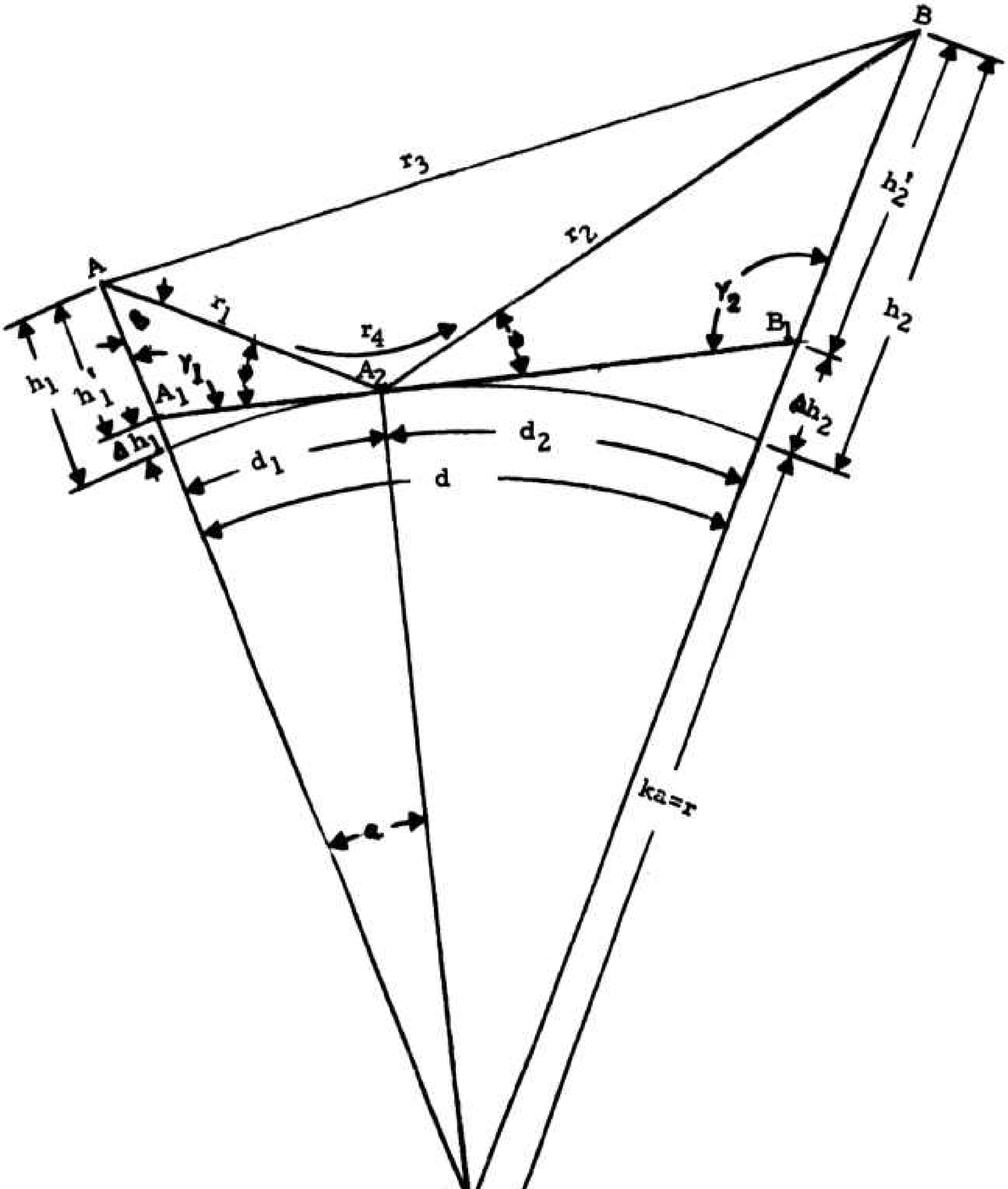

Figure E4 Geometry of Two-Path Propagation

where ψ is the angle of incidence and n is the index of refraction. For a horizontally polarized ray, this ratio is equal to

$$R_H = \frac{E_r}{E_i} = \frac{\sin\psi - \sqrt{n^2 - \cos^2\psi}}{\sin\psi + \sqrt{n^2 - \cos^2\psi}} = |R_H| e^{j\phi_h} \quad (12)$$

The reflected ray E_r can be expressed as $E_r = E_i |R| e^{j\phi}$ where ϕ is the angular phase change in the reflected ray. When ϕ is positive E_r will lead E_i and when it is negative E_r will lag E_i. By convention ϕ is normally expressed as the angle of lag even though it may be over 180 degrees.

To complete the evaluation of the reflection coefficient, the index of refraction must be calculated. It can be shown that n^2, expressed in MKS units, is equal to

$$n^2 = \frac{\varepsilon_{r2} - \dfrac{j\sigma_2}{\omega\varepsilon_0}}{\varepsilon_{r1}} \quad (13)$$

ε_0 = permittivity of free space $1/(36\pi \times 10^9)$ farad per meter

ε_{r1} = relative permittivity of air = 1

ε_{r2} = relative permittivity of reflecting surface

σ_2 = conductivity of reflecting surface MHO - meter/square meter

ω = $2\pi f$ angular frequency in radians/second

With ε_{r1} = 1 and frequency f in MHz, the equation reduces to

$$n^2 = \varepsilon_{r2} - j\,18 \times 10^3 \sigma_2 / f_{MHz} \quad (14)$$

Some typical values for ε_{r2} and σ_2 in the UHF range are (reference 5):

Material	ε_{r2}	σ_2
sea water	81	3 to 5
fresh water	81	10^{-2} to 10^{-3}
wet earth	5 to 30	10^{-1} to 10^{-3}
dry earth	2 to 5	10^{-4} to 10^{-5}

GEOMETRIC RELATIONSHIP

To use the above equations five parameters must be calculated from the geometric relationships involved in the problem. These parameters are d_1, d_2, h_2', θ, and ψ as shown in figure E4, with θ being the difference in physical path length of the direct ray r_3 and reflected ray r_4.

Since the earth radius is much greater than d_1, the angle ψ can be approximated by

$$\psi \approx \tan^{-1} \frac{h_1'}{5280 d_1} = \tan^{-1} \frac{h_2'}{5280 d_2} \tag{15}$$

where d_1 and d_2 are measured in statute miles and h_1, h_1', Δh_1, h_2, h_2', Δh_2 are measured in feet with $h_1' = h_1 - \Delta h_1$ and $h_2' = h_2 - \Delta h_2$. From figure E4

$$\cos \alpha = \frac{ka}{ka + \Delta h_1}$$

which gives

$$ka + \Delta h_1 = ka/\cos \alpha$$

additionally

$$\alpha = \frac{d_1}{ka}$$

Using the series approximation for $\cos \alpha$ which is

$$\cos \alpha \approx 1 - \left(\frac{\alpha^2}{2!}\right) + \left(\frac{\alpha^4}{4!}\right) \cdot \cdot \cdot \cdot$$

and taking the first two terms will give

$$\frac{ka}{\cos \alpha} = \frac{ka}{\cos \left(\frac{d_1}{ka}\right)} \approx \frac{ka}{1 - \frac{1}{2}\left(\frac{d_1}{ka}\right)^2} = ka + \frac{d_1^2}{2ka} \tag{16}$$

therefore

$$ka + \Delta h_1 = ka + \frac{d_1^2}{2ka} \tag{17}$$

and

$$\Delta h_1 = \frac{d_1^2}{2ka} \tag{18}$$

Expressing Δh_1 in feet; d_1 in statute miles; and ka, using the 4/3 earth radius factor to correct for atmospheric refraction, as 5280 statute miles the above equation will reduce to the final form of Δh_1 as

$$\Delta h_1 = \frac{d_1^{\,2}}{2} \tag{19}$$

A similar technique will give

$$\Delta h_2 = \frac{d_2^{\,2}}{2} \tag{20}$$

To develop the equation for the physical path length difference the quadrilateral AA_1B_1B in figure E4 is approximated by the trapezoid AA_1B_1B in figure E5. The difference in the length of the direct ray r_1 and the reflected ray r_2, in degrees of a wave length is given by

$$\theta = \frac{360}{\lambda}(r_2 - r_1) \tag{21}$$

where

λ = wave length of signal

The length of both rays can be calculated from triangles $AB_1'B$ and A_2B_2B which gives

$$r_1 = \sqrt{d^2 + (h_2' - h_1')^2} \tag{22}$$

$$r_2 = \sqrt{d^2 + (h_2' + h_1')^2} \tag{23}$$

These two equations can be expanded using the binomial expansion and since $d \gg h_2' + h_1'$ the higher order terms can be neglected which gives

$$r_1 \approx d + \frac{(h_2' - h_1')^2}{2d} \tag{24}$$

$$r_2 \approx d + \frac{(h_2' + h_1')^2}{2d} \tag{25}$$

therefore

$$r_2 - r_1 \approx \frac{2h_1'h_2'}{d} \tag{26}$$

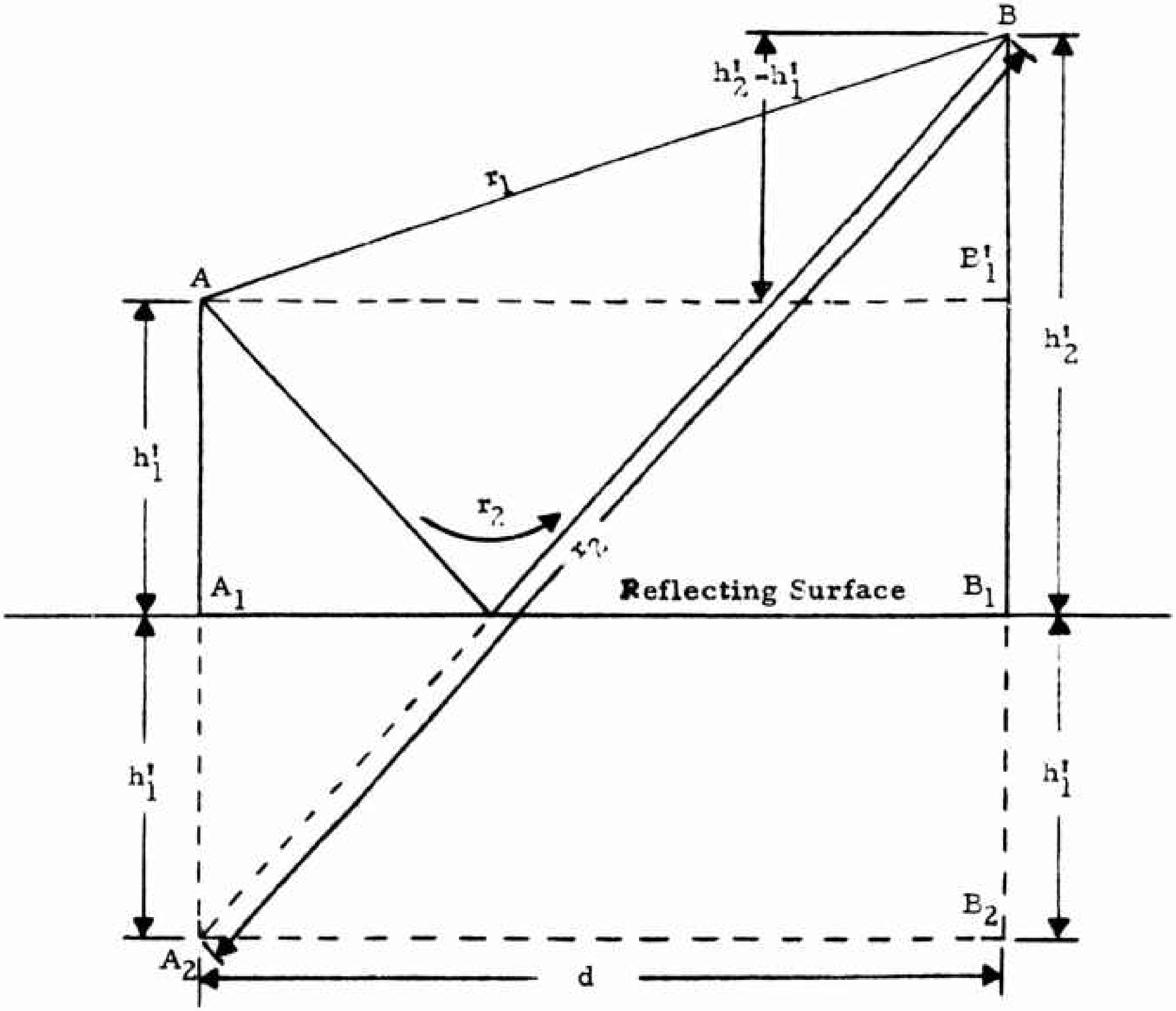

Figure E5 Path Length Difference

Which after converting units: h_1' and h_2' to feet, d in statute miles, and f in MHz gives the final working equation

$$\theta = \frac{1.385 \times 10^{-4}\ h_1' h_2' f_{MHz}}{d_{miles}} \text{ degrees} \tag{27}$$

The final equation required to complete the solution of the multipath effect is the relationship between h_1' and h_2' (figure E4). This can be approximated by the following:

Since

$ka >> d$

$d_1 \approx \overline{A_1A_2}$

$d_2 \approx \overline{B_1A_2}$

and angle $\gamma_1 \approx \gamma_2 \approx 90$ degrees; therefore, by similar triangles

$$\frac{h_2'}{h_1'} \approx \frac{d_2}{d_1} \tag{28}$$

SOLUTION OF EQUATIONS

The solution to these equations, as performed by program MULT (appendix C), is started with the calculation of the reflection distance d_1 which is necessary to solve the geometric problem at the given distance and height of the aircraft. The technique used is an iterative procedure of incrementing d_1 and solving for h_2 until h_2 equals the aircraft's altitude. The following equations are used during the determination of d_1:

$$d_2 = d - d_1$$

$$\Delta h_1 = \frac{d_1^{\,2}}{2} \tag{19}$$

$$\Delta h_2 = \frac{d_2^{\,2}}{2} \tag{20}$$

$$h_1' = h_1 - \Delta h_1$$

$$h_2' = \frac{h_1'\ d_2}{d_1} \tag{26}$$

$$h_2 = h_2' + \Delta h_2$$

When h_2 best approximates the altitude of the aircraft the final gain is calculated with the following equations:

$$\psi = \tan^{-1}\left(\frac{h_1'}{5280 d_1}\right) \tag{15}$$

$$\theta = \frac{1.385 \times 10^{-4}\ h_1' h_2'\ f_{MHz}}{d} \tag{27}$$

$$n^2 = \varepsilon_{r2} - \frac{j\ 18 \times 10^3\ \sigma_2}{f_{MHz}} \tag{14}$$

if the calculation is for horizontal polarization use

$$R_H = \frac{\sin\psi - \sqrt{n^2 - \cos^2\psi}}{\sin\psi + \sqrt{n^2 - \cos^2\psi}} \tag{12}$$

if the calculation is for vertical polarization use

$$R_v = \frac{n^2 \sin\psi - \sqrt{n^2 - \cos^2\psi}}{n^2 \sin\psi + \sqrt{n^2 - \cos^2\psi}} \tag{11}$$

$$\phi = \tan^{-1}\left(\frac{I_m\{R\}}{R_e\{R\}}\right)$$

where $I_m\{R\}$ is the imaginary portion of R and $R_e\{R\}$ is the real portion of R.

$$R = |R|$$

$$D = \left[1 + \frac{2 d_1 d_2^2}{d h_2'}\right]^{-\frac{1}{2}} \tag{10}$$

$$g(\theta)_{db} = 10 \log\left(\sqrt{1 + (DR)^2 + 2DR(\theta - \phi)}\right) \tag{6}$$

These equations can be solved for each range and altitude desired, producing a graph of the predicted multipath propagation effect.

APPENDIX F

ARPMP SOURCE LISTING

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      PROGRAM ADAP(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
     1 TAPE12)
      COMMON TAG(100),SIGNL(100),DPANG(100),ASPANG(100),TSIG(720),
     1  ANGAR(720),RANGAR(720),IDATA(8),IBCD(7),XARRAY(20),YARRAY(20),
     2   CNT(720),ATAG,RNG(100),TIM(100),STIM,SPTIM,SIG(2000),
     3   RANGE(2000),TIME(2000),MXSIG,MXRNG,LL,RMINS,RMAXS,SDEV(720),
     4   ASP(720),MINSIG,MINRNG
C
C        THIS IS AN ANTENNA DATA ANALYSIS SOFTWARE PACKAGE,
C            OPTIONS AVAILABLE TO THE USER ARE:
C                A) PLOT DATA ON POLAR PLOTS OR RANGE PLOTS
C                B) MATCH PERMITTIVITIES OF PREDICTED DATA AND
C                      ACTUAL FLIGHT DATA
C                C) PREDICT SIGNAL GAIN DUE TO MULTIPATH EFFECTS
C                D) MERGE UP TO THREE RADAR TAPES TOGETHER
C
C               READ ADAP CARD NO. 1
C
110   READ (5,180) ITYPE
      IF (EOF(5).NE.0) GO TO 160
      ICK=0
      IF (ITYPE.NE.4HPLOT) GO TO 120
      ICK=1
      WRITE (6,200)
      CALL OVERLAY (6HMPLOTS,1,0)
      GO TO 150
120   IF (ITYPE.NE.5HMATCH) GO TO 130
      ICK=1
      WRITE (6,210)
      CALL OVERLAY (5HMATCH,2,0)
      GO TO 150
130   IF (ITYPE.NE.4HMULT) GO TO 140
      ICK=1
      WRITE (6,220)
      CALL OVERLAY (4HMULT,3,0)
      GO TO 150
140   IF (ITYPE.NE.5HMERGE) GO TO 150
      ICK=1
      WRITE (6,190)
      CALL OVERLAY (7HRDMERGE,4,0)
150   IF (ICK.NE.0) GO TO 160
      WRITE (6,170) ITYPE
160   STOP
C
170   FORMAT (1H ,14H PROGRAM NAME ,A5,21H IS NOT A LEGAL NAME ,//,39H
     1LEGAL NAMES ARE MERGE,PLOT,MATCH,MULT)
180   FORMAT (A10)
190   FORMAT (31H RADAR MERGE PROGRAM IS CALLED )
200   FORMAT (27H PLOTTING PROGRAM IS CALLED)
210   FORMAT (37H MULTIPATH MATCHING PROGRAM IS CALLED)
220   FORMAT (40H MULTIPATH PREDICTION PROGRAM IS CALLED )
      END
```

```
      OVERLAY(MPLOTS,1,0)
C
C        THIS IS THE MASTER PLOT SUBROUTINE WHICH INITIALIZES DATA AND
C        CALLS EITHER THE POLAR PLOT PROGRAM PPLOTS OR THE RANGE VS
C        SIGNAL PLOT PROGRAM SPLOTS
C
      PROGRAM MPLOTS
      COMMON TAG(100),SIGNL(100),DPANG(100),ASPANG(100),TSIG(720),
     1  ANGAR(720),RANGAR(720),IDATA(8),IBCD(7),XARRAY(20),YARRAY(20),
     2   CNT(720),ATAG,RNG(100),TIM(100),STIM,SPTIM,SIG(2000),
     3   RANGE(2000),TIME(2000),MXSIG,MXRNG,LL,RMINS,RMAXS,SDEV(720),
     4   ASP(720),MINSIG,MINRNG
      REAL MXSIG,MXRNG
      CALL PLOTS (DUM,DUM,13)
C
C         IF ITYPE IS EQUAL TO P; THEN POLAR PLOTS WILL BE PRODUCED
C          IF ITYPE IS EQUAL TO S; THEN RANGE VS. SIGNAL PLOTS WILL
C           BE PRODUCED
C
      LL=1
10    REWIND 12
      DO 20 M=1,100
      TAG(M)=0.0
      SIGNL(M)=0.0
      DPANG(M)=0.0
      ASPANG(M)=0.0
      RNG(M)=0.0
      TIM(M)=0.0
20    CONTINUE
      DO 30 M=1,720
      SDEV(M)=0.0
      ASP(M)=(M-1)*.5
      TSIG(M)=0.0
      CNT(M)=0.0
      ANGAR(M)=0.0
      RANGAR(M)=0.0
30    CONTINUE
      DO 40 M=1,2000
      SIG(M)=0.0
      RANGE(M)=0.0
      TIME(M)=0.0
40    CONTINUE
C
C     ITYPE, THE START AND STOP TIMES TO BE PLOTTED ARE READ IN
```

```
C
C           ADAP CARD NO. 3
C
      READ (5,60) ITYPE,IHR1,MIN1,ISEC1,IHR2,MIN2,ISEC2
      IF (EOF(5).NE.0.0) GO TO 50
C
C     THE SOURCE NUMBER,THE MIN AND MAX SIGNAL AND RANGE; AND
C     THE MIN AND MAX VALUE TO BE USED FOR WILD POINT CHECK IS
C     READ IN;    ADAP CARD NO. 4
C
      READ (5,70) ATAG,MINSIG,MXSIG,MINRNG,MXRNG,RMINS,RMAXS
      WRITE (6,80) IHR1,MIN1,ISEC1,IHR2,MIN2,ISEC2,ATAG,MINSIG,MXSIG,MIN
     1RNG,MXRNG,RMINS,RMAXS
      STIM=IHR1*3600.+MIN1*60.+ISEC1*1.
      SPTIM=IHR2*3600.+MIN2*60.+ISEC2*1.
      IF (ITYPE.EQ.1HP) CALL PPLOTS
      IF (ITYPE.EQ.1HS) CALL SPLOTS
      GO TO 10
50    CALL PLOT (0.,0.,999)
      WRITE (6,90)
      STOP
C
60    FORMAT (A1,3X,3I2,4X,3I2)
70    FORMAT (8F10.3)
80    FORMAT (1H1,48HIF ITYPE = P, THEN POLAR PLOTS WILL BE PRODUCED ,/,
     11X,58HIF ITYPE = S, THEN RANGE VS. SIGNAL PLOTS WILL BE PRODUCED,/
     2,1X,17HTHE START TIME IS,2X,3I2,2X,16HTHE STOP TIME IS,2X,3I2,/,1X
     3,18H THE SOURCE NO. IS,F10.3,/,37H THE MINIMUM SIGNAL TO BE PLOTTE
     4D IS ,F10.3,1X,21HTHE MAXIMUM SIGNAL IS,F10.3,/,29H THE MINUMUM RA
     5NGE PLOTTED IS,F10.3,30H THE MAXIMUM RANGE PLOTTED IS ,F10.3,/,25H
     6 DATA THAT IS  LESS THAN ,F10.3,17H OR GREATER THAN ,F10.3,1X,19HW
     7ILL NOT BE PLOTTED)
90    FORMAT (26H END OF DATA TO BE PLOTTED)
      END


      SUBROUTINE PPLOTS
C
C       POLAR PLOTS WILL BE PRODUCED; EFFECTIVE RADIATED POWER
C         WILL BE PLOTTED VERSUS THE AZIMUTH ANGLE OF THE AIRCRAFT
C
      COMMON TAG(100),SIGNL(10C),DPANG(1CO),ASPANG(100),TSIG(720),
     1  ANGAR(720),RANGAR(720),IDATA(8),IBCD(7),XARRAY(20),YARRAY(20),
     2   CNT(720),ATAG,RNG(100),TIM(100),STIM,SPTIM,SIG(2000),
     3   RANGE(2000),TIME(2000),MXSIG,MXRNG,LL,RMINS,RMAXS,SDEV(720),
     4   ASP(720)
      REAL MXSIG,MXRNG
C
C       THE DEPRESSION ANGLE, SIGNAL INTERVAL TO BE PLOTTED IS READ IN.
C         DELD IS THE DEPRESSION ANGLE INTERVAL; IPLANE IDENTIFIES
C         THE AIRCRAFT TO BE DRAWN AT CENTER OF PLOT. IPAPER IDENTIFIES
C         WHETHER OR NOT THE GRID ROUTINE IS TO BE CALLED TO DRAW THE
C         POLAR GRID; IBCD IS A 70 COLUMN COMMENT THAT IS DRAWN AT THE
C         TOP OF THE PLOT
C
      DIMENSION SG(720),CT(720),AP(720),SD(720)
      TLAST=C.
      WRITE (6,210)
C
C         READ ADAP CARD NO. 5
C
      READ (5,230) IBCD
C
C         READ ADAP CARD NO. 6
C
      READ (5,220) ANG,SINT,DELD,IPLANE,IPAPER
      IF (IPAPER.NE.0) CALL PLOT (0.,5.5,-3)
      ANG1=ANG-DELD
      ANG2=ANG+DELD
      RBIAS=(4-(MXSIG/SINT))*SINT
C
C      DATA IS READ FROM OUTPUT FILE OF ARPMP
C
10    READ (12) (TAG(I),SIGNL(I),DPANG(I),ASPANG(I),RNG(I),TIM(I),I=1,80
     1),WDNO
      NWD=WDNO/6
      IF (EOF(12).NE.0.0) GO TO 190
      TLAST=TIM(NWD)
C
C          DATA IS SUMMED AND STORED FOR EACH DATA CELL
C
      DO 3C J=1,NWD
      IF (STIM.GT.TIM(J)) GO TO 30
      IF (TIM(J).GT.SPTIM) GO TO 40
      IF (ANG.EQ.999.) GO TO 20
      IF (DPANG(J).LT.ANG1.OR.DPANG(J).GT.ANG2) GO TO 30
20    IF (ATAG.NE.TAG(J)) GO TO 30
      IF (SIGNL(J).LT.RMINS.OR.SIGNL(J).GT.RMAXS) GO TO 30
      II=ASPANG(J)*2+1.50
      IF (II.GT.720) II=1
      CNT(II)=CNT(II)+1
      TSIG(II)=TSIG(II)+SIGNL(J)
      SDEV(II)=SDEV(II)+SIGNL(J)*SIGNL(J)
30    CONTINUE
      GO TO 10
C
C           DATA IS AVERAGED AND THE STANDARD DEVIATION IS CALCULATED
C
40    DO 50 J=1,720
```

```
      IF (CNT(J).EQ.0) GO TO 50
      TSIG(J)=TSIG(J)/CNT(J)
      IF (CNT(J).LT.2) SDEV(J)=0.
      IF (CNT(J).LT.2) GO TO 50
      SDEV(J)=SQRT((SDEV(J)-TSIG(J)*TSIG(J)*CNT(J))/(CNT(J)-1))
   50 CONTINUE
      L1=0
C
C         DATA CELLS WITH NO DATA ARE THROWN OUT
C
      DO 60 J=1,720
      IF (CNT(J).EQ.0.0) GO TO 60
      L1=L1+1
      SG(L1)=TSIG(J)
      CT(L1)=CNT(J)
      AP(L1)=ASP(J)
      SD(L1)=SDEV(J)
   60 CONTINUE
      IF (L1.LT.200) GO TO 70
      K1=1
      K2=200
      GO TO 80
   70 K1=1
      K2=L1
C
C        DATA TO BE PLOTTED IS PRINTED ON LINE PRINTER
C
   80 DO 90 NN=1,4
      WRITE (6,240) IBCD,L1
      WRITE (6,250) ANG,DELD,SINT,IPLANE,(AP(J),SG(J),SD(J),CT(J),J K1,K
     12)
      K1=K1+200
      K2=K2+200
      IF (K2.GE.L1) GO TO 100
      IF (K2.GT.720) K2=720
   90 CONTINUE
C
C       IF IPAPER NOT EQUAL TO ZERO; POLAR GRID IS DRAWN BY
C         SUBROUTINE GRID
C
  100 IF (IPAPER.NE.0) CALL GRID
      IDATA(1)=10H AZIMUTH I
      IDATA(2)=10HS RELATIVE
      IDATA(3)=10H TO A/C HE
      IDATA(4)=10HADING
      CALL NEWPEN(2)
      CALL SYMBOL (-3.5,4.8,.10,IBCD,0.,70)
      YPAGE=4.0
  110 CALL NUMBER (.15,YPAGE,.10,MXSIG,0.,2)
      CALL SYMBOL (999.,999.,.10,4H DBW,0.,4)
      IF (YPAGE.LE.1.) GO TO 120
      MXSIG=MXSIG-SINT
      YPAGE=YPAGE-1.
      GO TO 110
  120 CALL SYMBOL (-1.8,-4.8,.10,IDATA,0.,40)
      CALL SYMBOL (0.,0.,.10,3,0.,-1)
C
C        PLANE IS DRAWN AT CENTER OF PLOT
C
      CALL PLANE (IPLANE)
      CALL NEWPEN(1)
      K=1
      NZERO=0
      DO 180 J=1,720
      IF (CNT(J).NE.0) GO TO 130
      NZERO=NZERO+1
C
C     IF 5 DEG ASP WITH NO DATA, PLOT DATA SEGMENT
C
      IF (NZERO.EQ.10) GO TO 140
      GO TO 170
C
C       DATA IS PACKED INTO THE PLOTTING ARRAYS
C
  130 RANGAR(K)=TSIG(J)+RBIAS
      ANGAR(K)=-1*((J-1)*.5-90)/57.4
      K=K+1
      NZERO=0
      GO TO 170
  140 IF (K.GE.2) GO TO 150
C
C        1 POINT IS PLOTTED WITHOUT CONNECTING LINE
C
      CALL POLAR (RANGAR,ANGAR,K-1,1,-1,3,0.,SINT)
      GO TO 160
C
C        POINTS ARE PLOTTED WITH CONNECTING LINES
C
  150 CALL POLAR (RANGAR,ANGAR,K-1,1,1,3,0.,SINT)
  160 K=1
      NZERO=0
      GO TO 180
  170 IF (J.EQ.720) GO TO 140
  180 CONTINUE
      WRITE (6,260) LL
      IF (IPAPER.NE.0) CALL PLOT (14.,-5.5,-3)
      IF (IPAPER.EQ.0) CALL PLOT (12.,0.,-3)
      LL=LL+1
      RETURN
  190 WRITE (6,270) TLAST
```

```
      DO 200 J=1,720
      IF (CNT(J).NE.0) GO TO 40
200   CONTINUE
C
210   FORMAT (43H  ITYPE = P ; POLAR PLOTS WILL BE PRODUCED )
220   FORMAT (3F10.3,2I1)
230   FORMAT (8A10)
240   FORMAT (1H1,28X,7A10,/,28X,I4,22H POINTS TO BE PLOTTED )
250   FORMAT (1H ,20X,34HPLOTTED DATA FOR DEPRESSION ANGLE ,F10.3,17H PL
     1US   OR MINUS ,F10.3,6H DEGS.,/,24H THE SIGNAL INTERVAL IS ,F10.3,
     210H IPLANE = ,I1,/,4(33H   ASP ANG  SIGNAL  STDEV  COUNT ),/,200(1
     3X,16F8.2,/))
260   FORMAT (1X,18HPOLAR PLOT NUMBER ,1X,I2,9H PLOTTED )
270   FORMAT (49H END OF FILE  --TAPE 12  LAST TIME PROCESSED WAS ,F10.3
     1)
      END


      SUBROUTINE PLANE (ITYP)
C
C        THIS SUBROUTINE DRAWS THE A/C IN THE CENTER OF THE POLAR PLOT.
C        IF A DIFFERENT VIEW OF THE A/C IS NEEDED, IT MAY BE ADDED IN
C        THIS ROUTINE WITH ITYP BEING USED TO IDENTIFY WHICH A/C IS TO
C        BE DRAWN.
C
      DIMENSION XARRAY(20),YARRAY(20)
      XARRAY(1)=-.5
      XARRAY(2)=-.1666
      XARRAY(3)=0.0
      XARRAY(4)=.1666
      XARRAY(5)=.5
      XARRAY(6)=.1666
      XARRAY(7)=.0833
      XARRAY(8)=.0833
      XARRAY(9)=+.1666
      XARRAY(10)=-.1666
      XARRAY(11)=-.0833
      XARRAY(12)=-.0833
      XARRAY(13)=-.1666
      XARRAY(14)=-.5
      XARRAY(15)=0.0
      XARRAY(16)=2.
      YARRAY(1)=-.1666
      YARRAY(2)=0.
      YARRAY(3)=.5
      YARRAY(4)=0.
      YARRAY(5)=-.1666
      YARRAY(6)=-.1666
      YARRAY(7)=-.3333
      YARRAY(8)=-.4
      YARRAY(9)=-.42
      YARRAY(10)=-.42
      YARRAY(11)=-.4
      YARRAY(12)=-.3333
      YARRAY(13)=-.1666
      YARRAY(14)=-.1666
      YARRAY(15)=0.0
      YARRAY(16)=2.
      CALL LINE (XARRAY,YARRAY,14,1,0,0)
      RETURN
      END


      SUBROUTINE SPLOTS
C
C        RANGE VS. SIGNAL (EFFECTIVE RADIATED POWER) PLOTS ARE DRAWN
C
      COMMON TAG(100),SIGNL(100),DPANG(100),ASPANG(100),TSIG(720),
     1  ANGAR(720),RANGAR(720),IDATA(3),IBCD(7),XARRAY(20),YARRAY(20),
     2   CNT(720),ATAG,RNG(100),TIM(100),STIM,SPTIM,SIG(2000),
     3   RANGE(2000),TIME(2000),MXSIG,MXRNG,LL,RMINS,RMAXS,SDEV(720),
     4   ASP(720),MINSIG,MINRNG
      DIMENSION ST(2)
      REAL MXRNG,MXSIG,MINSIG,MINRNG
      TLAST=0.
      WRITE (6,170)
C
C        READ ADAP CARD 5
C
      READ(5,190) IBCD
C
C        READ ADAP CARD NO. 7
C
      READ(5,180) XLEN,YLEN
      ST(1)=MINRNG
      ST(2)=MINSIG
      XINT=(MXRNG-ST(1))/XLEN
      YINT=(MXSIG-ST(2))/YLEN
      ICK=0
      N=0
C
C       CONTROL CARDS ARE PRINTED
C
      WRITE (6,200) XLEN,YLEN,ST(1),ST(2),XINT
C
C        DATA IS READ FROM OUTPUT FILES OF ARPMP
C
10    READ (12) (TAG(I),SIGNL(I),DPANG(I),ASPANG(I),RNG(I),TIM(I),I=1,80
```

```
      1),WDNO
      K=WDNO/6
      IF (EOF(12).NE.0.0) GO TO 160
      TLAST=TIM(K)
C
C         DATA IS STORED IN THE ARRAYS SIG,RANGE AND TIME
C
      DO 20 J=1,K
      IF (STIM.GT.TIM(J)) GO TO 20
      IF (TIM(J).GT.SPTIM) GO TO 30
      IF (ATAG.NE.TAG(J)) GO TO 20
      IF (SIGNL(J).LT.RMINS.OR.SIGNL(J).GT.RMAXS) GO TO 20
      N=N+1
      SIG(N)=SIGNL(J)
      RANGE(N)=RNG(J)
      TIME(N)=TIM(J)
      IF (N.EQ.1998) GO TO 30
   20 CONTINUE
      GO TO 10
C
C      DATA LESS THAN THE MINIMUM SIGNAL AND GREATER THAN THE MAXIMUM
C        SIGNAL THAT WAS READ IN IS THROWN OUT
C
   30 NN=N
      DO 50 J=1,NN
      IF (J.GT.N) GO TO 60
      IF (SIG(J).GE.ST(2).AND.SIG(J).LE.MXSIG) GO TO 50
      WRITE (6,210) SIG(J),RANGE(J),TIM(J)
      JK=J
      KK=N-1
      DO 40 KJ=JK,KK
      SIG(KJ)=SIG(KJ+1)
      RANGE(KJ)=RANGE(KJ+1)
   40 CONTINUE
      N=N-1
   50 CONTINUE
C
C      DATA TO BE PLOTTED IS PRINTED
C
   60 WRITE (6,220) IBCD
      WRITE (6,230) N,(SIG(I),RANGE(I),I=1,N)
      IF (ICK.EQ.1.) GO TO 150
      ICK=1
      XPAGE=XLEN
      CALL PLOT (0.,1.,-3)
      CALL PLOT (XPAGE,0.,2)
C
C         X-AXIS IS DRAWN
C
   70 IF (XPAGE.LE.0.0) GO TO 80
      CALL SYMBOL (XPAGE,0.,.1,13,0.,-1)
      XPAGE=XPAGE-.5
      GO TO 70
   80 XPAGE=-.15
C
C          X-AXIS LABELING IS DRAWN
C
      VAL=ST(1)
      CALL NUMBER (XPAGE,-.2,.1,VAL,0.,2)
      VAL=VAL+XINT
      XPAGE=XPAGE+.9
      K=XLEN
      DO 90 I=1,K
      IF (XPAGE.GT.XLEN) GO TO 100
      CALL NUMBER (XPAGE,-.2,.1,VAL,0.,2)
      VAL=VAL+XINT
      XPAGE=XPAGE+1.0
   90 CONTINUE
  100 YPAGE=-.6
      IDATA(1)=10HRANGE NM
      XPAGE=XLEN/2.-.5
      CALL SYMBOL (XPAGE,YPAGE,.15,IDATA,0.,10)
      CALL PLOT (0.,0.,3)
C
C         Y-AXIS IS DRAWN
C
      CALL PLOT (0.,YLEN,2)
      YPAGE=YLEN
  110 IF (YPAGE.LE.0.0) GO TO 120
      CALL SYMBOL (0.,YPAGE,.1,13,90.,-1)
      YPAGE=YPAGE-.5
      GO TO 110
  120 XPAGE=-.4
      YPAGE=0.0
C
C         Y-AXIS LABELING IS DRAWN
C
      VAL=ST(2)
      CALL NUMBER (XPAGE,YPAGE,.1,VAL,0.,2)
      K=YLEN
      VAL=VAL+YINT
      YPAGE=YPAGE+1.
      XPAGE=XPAGE-.1
      DO 130 I=1,K
      IF (YPAGE.GT.YLEN) GO TO 140
      CALL NUMBER (XPAGE,YPAGE,.1,VAL,0.,2)
      VAL=VAL+YINT
      YPAGE=YPAGE+1.0
  130 CONTINUE
  140 XPAGE=XLEN/2.-6.
```

```
      IF (XPAGE.LT.0) XPAGE=0.
      YPAGE=YLEN+.40
      CALL SYMBOL (XPAGE,YPAGE,.15,IBCD,0.,70)
      IDATA(1)=10HSIGNAL DBW
      XPAGE=-.8
      YPAGE=3.5
      CALL SYMBOL (XPAGE,YPAGE,.15,IDATA,90.,10)
C
C        FIRST POINT AND SCALING DATA IS LOADED INTO THE PLOTTING
C          ARRAYS FOR CALL OF LINE ROUTINE TO DRAW THE DATA CURVE
C
  150 RANGE(N+1)=ST(1)
      RANGE(N+2)=XINT
      SIG(N+1)=ST(2)
      SIG(N+2)=YINT
C
C        DATA CURVE IS DRAWN
C
      CALL LINE (RANGE,SIG,N,1,0,C)
      KN=WDNO/6
      N=0
C
C        CHECK IS MADE TO SEE IF MORE TIME IS LEFT IN THE TIME INTERVAL
C        TO BE PLOTTED--IF SO CONTROL IS TRANSFERRED BACK TO STATEMENT
C        10 AND MORE DATA IS READ FROM THE OUTPUT FILE OF ARPMP
C
      IF (TIM(KN).LT.SPTIM) GO TO 10
      WRITE (6,240) LL,TLAST
      LL=LL+1
      CALL PLOT (XLEN+6.,-1.,-3)
      RETURN
  160 WRITE (6,250) TLAST
      STOP
C
  170 FORMAT (50H ITYPE= S; RANGE VS SIGNAL PLOTS WILL BE PRODUCED )
  180 FORMAT (8F10.3)
  190 FORMAT (8A10)
  200 FORMAT (26H THE THE X-AXIS LENGTH IS ,F10.3,21H THE Y-AXIS LENGTH
     1IS,F10.3,/,1X,22HTHE STARTING RANGE IS ,F10.3,20H THE START SIGNAL
     2 IS,F10.3,/,1X,24H THE X AXIS INTERVAL IS ,F10.3)
  210 FORMAT (1H ,40H THE DATA POINT THAT IS OUT OF RANGE IS ,F10.3,15H
     1AT A RANGE OF ,F10.3,14H AT A TIME OF ,F10.3)
  220 FORMAT (1H1,20X,8A10)
  230 FORMAT (1H0,35X,39H RANGE VS. SIGNAL ANTENNA PATTERN PLOT ,/,35X,3
     19H THE NUMBER OF DATA POINTS TO PLOT ARE ,I10,/,35X,21H THE DATA A
     2RRAYS ARE ,//,1X,6(2X,6HSIGNAL,5X,5HRANGE,2X),//,170(1X,12F10.3,/)
     3)
  240 FORMAT (13H PLOT NUMBER ,I10,33H PLOTTED   LAST TIME ON PLOT WAS ,
     1F10.3)
  250 FORMAT (1H ,59HEND OF FILE ENCOUNTERED TAPE 12 LAST TIME PROCESSED
     1    WAS ,F10.3)
      END


      SUBROUTINE GRID
C
C        THIS SUBROUTINE DRAWS A POLAR COORDINATE GRID
C
      DIMENSION RAD(2),ANGL(2),IBCD(8)
C
C       A CALL IS MADE TO FUNCTION NEWPEN TO DEFINE A NEW PEN FOR
C         USE IN DRAWING A POLAR GRID (THUS A DIFFERENT COLOR MAY
C         USED FOR THE GRID)
C
      CALL NEWPEN (2)
      RAD(1)=.5
      RAD(2)=4.5
      ANGL(1)=80./57.4
      ANGL(2)=80./57.4
      DEG=10.
C
C        RADIALS ARE DRAWN EVERY 10 DEGREES
C
      DO 10 I=1,36
      CALL POLAR (RAD,ANGL,2,1,0,0,-5.,1.)
      XPAGE=4.6*SIN(90./57.4-ANGL(1))
      YPAGE=4.6*COS(90./57.4-ANGL(1))
      IF (DEG.GT.180.) XPAGE=XPAGE-.43
      CALL NUMBER (XPAGE,YPAGE,.10,DEG,0.,0)
      ANGL(1)=ANGL(1)-10./57.4
      ANGL(2)=ANGL(1)
      DEG=DEG+10
   10 CONTINUE
      XPAGE=.5
      RO=.5
      RF=.5
      DO 20 I=1,9
C
C        A CIRCLE IS DRAWN EVERY HALF-INCH
C
      CALL CIRCL (XPAGE,0.,0.,360.,RO,RF,0.)
      XPAGE=XPAGE+.5
      RO=RO+.5
      RF=RF+.5
   20 CONTINUE
C
C        A BORDER IS DRAWN ABOUT THE PLOTS
C
      CALL PLOT (-6.,-5.,3)
```

```
      CALL PLOT (-6.,5.,2)
      CALL PLOT (6.,5.,2)
      CALL PLOT (6.,-5.,2)
      CALL PLOT (-6.,-5.,2)
      CALL NEWPEN (1)
      RETURN
      END

      OVERLAY(MATCH,2,0)
C
C       CVERLAY MATCH DETERMINES THE PERMITTIVITY WHICH PRODUCES THE
C         BEST ELIMINATION OF MULTIPATH SIGNALS
C
      PROGRAM MATCH
      REAL LASTVR
      COMPLEX REF
      DIMENSION SIG(101),PMULT(101),IHEAD(8),CNT(101),ISTR(3),ISTP(3),
     1 DSR(80),DSIG(80),DEP(80),ASP(80),RNG(80),TIM(80),DIF(101)
      WRITE (6,180)
   10 REWIND 11
      PERM=1.
      COND=.001
      ENT=1.
C
C       READ IN HEADING INFORMATION
C
C        READ ADAP CARD NO. 10
C
      READ (5,190) IHEAD
      IF (EOF(5).NE.0) GO TO 170
      WRITE (6,200) IHEAD
C
C        READ IN START TIME(HR,MIN,SEC),STOP TIME(HR,MIN,SEC),HEIGHT
C        OF ANTENNA ABOVE REFLECTING SURFACE IN FEET, HEIGHT OF
C        AIRCRAFT ABOVE ANTENNA IN FEET, FREQUENCY IN MHZ, AND
C        SOURCE NUMBER
C
C
C         READ ADAP CARD NO. 11
C
      READ (5,210) ISTR,ISTP,HT,ACHT,FREQ,ISR
      SR=ISR
C
C        CALCULATE THE START AND STOP TIMES IN TOTAL SECONDS
C
      START=ISTR(1)*3600.+ISTR(2)*60.+ISTR(3)
      STOP=ISTP(1)*3600.+ISTP(2)*60.+ISTP(3)
      WRITE (6,220) ISTR,START,ISTP,STOP,HT,ACHT,FREQ,ISR
      DO 20 I=1,101
      CNT(I)=0
      SIG(I)=0
   20 PMULT(I)=0.
C
C       READ DATA FROM OUTPUT FILE OF ARPMP
C
   30 READ (11) (DSR(I),DSIG(I),DEP(I),ASP(I),RNG(I),TIM(I),I=1,80),ANUM
      IF (EOF(11).NE.0) GO TO 140
      NUM=ANUM/6.
C
C       CHECK IF DATA IS WITHIN TIME INTERVAL AND PROPER SOURCE NUMBER
C
      DO 40 I=1,NUM
      IF (TIM(I).LT.START) GO TO 40
      IF (TIM(I).GE.STOP) GO TO 50
      IF (SR.NE.DSR(I)) GO TO 40
C
C        CALCULATE RANGE INDEX TO STORE THE SUM OF THE SIGNALS
C
      II=(RNG(I)-3.8)/.4+1
      IF (II.LT.1.OR.II.GT.101) GO TO 40
      SIG(II)=SIG(II)+DSIG(I)
      CNT(II)=CNT(II)+1
   40 CONTINUE
      GO TO 30
   50 DO 60 I=1,101
C
C        CALCULATE THE AVERAGE SIGNAL
C
      IF (CNT(I).EQ.0) GO TO 60
      SIG(I)=SIG(I)/CNT(I)
   60 CONTINUE
      IFIN=0
      LASTVR=100000000.
C
C        PERMITTIVITY(PERM) IS FIRST SET TO 1 TO CORRECT RADIAL FOR
C        MULTIPATH RADIATION PERM IS    INITIALLY INCREMENTED BY 1(ENT)
C        FOR EACH CORRECTION OF RADIAL UNTIL STANDARD DEVIATION
C        INCREASES.  PERM IS THEN REDUCED BY 1 AND ENT IS SET TO .1 AND
C        PROCESS IS REPEATED TO FIND BEST PERM.
C
C       START OF DO LOOP THAT DETERMINES PERMITTIVITY OF BEST FIT
C
      DO 120 I=1,20
      DO 70 J=1,101
      PMULT(J)=0
   70 DIF(J)=0
      REF=CMPLX(PERM,-COND*18000./FREQ)
C
```

```
C         CALCULATE MULTIPATH DB GAIN  FOR EACH RANGE CELL
C
      DO 80 J=1,101
      IF (SIG(J).EQ.0) GO TO 80
      RANGE=3.6+J*.4
      CALL MULTPTH (RANGE,REF,HT,ACHT,ICKMP,DBGAIN,FREQ)
C
C         IF ICKMP NE  ZERO DB GAIN CANNOT BE CALCULATED
C
      IF (ICKMP.NE.0) GO TO 80
      PMULT(J)=DBGAIN
80    CONTINUE
      SUM=0
      SCNT=0
C
C         SUBTRACT MULTIPATH GAIN FROM SIGNAL
C
      DO 90 J=1,101
      IF (SIG(J).EQ.0.OR.PMULT(J).EQ.0.) GO TO 90
      DIF(J)=SIG(J)-PMULT(J)
      SCNT=SCNT+1
      SUM=SUM+DIF(J)
90    CONTINUE
C
C          IF LESS THAN 10 RANGE CELLS OF DATA -- END RUN --
C
      IF (SCNT.LT.10) GO TO 150
      AVER=SUM/SCNT
      SUM2=0
      DO 100 J=1,101
      IF (DIF(J).EQ.0) GO TO 100
      SUM2=SUM2+(DIF(J)-AVER)**2
100   CONTINUE
C
C          CALCULATE STANDARD DEVIATION OF CORRECTED DATA
C
      VAR=SQRT(SUM2/(SCNT-1))
C
C          IF LAST CALCULATION, GO TO PRINT FINAL DATA
C
      IF (IFIN.EQ.1) GO TO 130
C
C          IF VARIANCE IS INCREASING REDUCE PERMITTIVITY
C
      IF (VAR.GT.LASTVR) GO TO 110
      LASTVR=VAR
      PERM=PERM+ENT
      GO TO 120
C
C          PERMITTIVITY INCREMENT IS ALREADY .1 SET END INDICATOR
C
110   IF (ENT.EQ..1) IFIN=1
      PERM=PERM-ENT
      IF (ENT.EQ.1) ENT=.1
120   CONTINUE
      GO TO 160
C
C       PRINT FINAL DATA
C
130   WRITE (6,230) PERM,COND,REF,AVER,VAR
      WRITE (6,240)
C
C         PRINT GRAPH OF SIGNAL
C
      CALL PRPT (SIG)
      WRITE (6,250)
C
C         PRINT GRAPH OF MULTIPATH EFFECT
C
      CALL PRPT (PMULT)
      WRITE (6,260)
C
C          PRINT GRAPH OF CORRECTED SIGNAL
C
      CALL PRPT (DIF)
      GO TO 10
140   WRITE (6,270) TIM(NUM)
      STOP
150   WRITE (6,280) SCNT
      STOP
160   WRITE (6,290)
170   STOP
C
180   FORMAT (1H1,/,1HT)
190   FORMAT (1X,8A10)
200   FORMAT (1H1,50X,26HMULTIPATH MATCHING PROGRAM,///,20X,8A10)
210   FORMAT (2(4X,3I2),3F10.2,I10)
220   FORMAT (1H ,/,14H START TIME = ,I4,3H HR,I4,4H MIN,I4,4H SEC,18H
     1    TOTAL SEC = ,F10.0,/,14H STOP TIME  = ,I4,3H HR,I4,4H MIN,I4,4
     2H SEC,19H          TOTAL SEC = ,F10.0,/,26H ANTENNA          HEIGHT =
     3,F10.3,25H AIRCRAFT ALTITUDE AGL = ,F10.0,16H FREQUENCY    = ,F10.
     43,17H SOURCE NUMBER = ,I3)
230   FORMAT (///,2(1H ,100(1H*),/),/,1H ,40H BEST FIT WAS FOUND WITH PE
     1RMITTIVITY = ,F10.2,16H CONDUCTIVITY = ,F10.3,/,14H    CALCULATED,
     216H REFLECTIVITY = ,2F10.2,1HJ,/,1H ,17H AVERAGE SIGNAL= ,F10.3,24
     3H    STANDARD DEVIATION = ,F10.3,///,2(1H ,100(1H*),/))
240   FORMAT (1H1,40X,43H PLOT OF SIGNAL DATA USED FOR CURVE FITTING,///
     1,5X,3HDBW)
250   FORMAT (1H1,40X,38H PLOT OF BEST FITTING MULTIPATH EFFECT,///,5X,2
     1HDB)
```

```
260   FORMAT (1H1,44X,35HPLOT OF MULTIPATH CORRECTED SIGNAL ,/,30X,59H (
     1 FOR A PERFECT FIT THIS CURVE SHOULD BE A CONSTANT DBW  ),//,5X,3H
     2DBW)
270   FORMAT (1H ,42HEND OF TAPE ENCOUNTERED LAST TIME READ WAS,F10.3)
280   FORMAT(1H ,6H ONLY ,F4.0,44H RANGE SAMPLES WERE FOUND CANNOT FIT C
     1URVE   )
290   FORMAT (1H ,49HBEST FIT STILL NOT FOUND FOR PERMITTIVITY 1 TO 20)
      END


      SUBROUTINE PRPT (SIG)
C
C         THIS SUBROUTINE CREATES A PRINTER PLOT OF THE ARRAY SIG
C
      DIMENSION SIG(101),MTRX(61,101),PR(13),RN(11),RRN(101)
      PR(1)=-5.
      DO 10 I=2,13
10    PR(I)=PR(I-1)+2.5
      DO 20 I=1,61
      DO 20 J=1,101
20    MTRX(I,J)=10H
C
C       LOOP WHICH SETS THE POINTS TO BE PLOTTED
C
      DO 30 I=1,101
      IF (SIG(I).EQ.0.) GO TO 30
      II=(SIG(I)+.25)*2+11
      IF (II.LT.1) II=1
      IF (II.GT.61) II=61
      MTRX(II,I)=1H.
30    CONTINUE
      WRITE (6,80)
      L=62
C
C         LOOP TO PRINT ARRAY
C
      DO 40 I=1,12
      L=L-1
      WRITE (6,90) PR(14-I),(MTRX(L,K),K=1,101)
      DO 40 J=1,4
      L=L-1
      WRITE (6,100) (MTRX(L,K),K=1,101)
40    CONTINUE
C
C         PRINT LAST LINE OF ARRAY
C
      WRITE (6,90) PR(1),(MTRX(1,K),K=1,101)
      WRITE (6,80)
C
C         SET VALUES OF RANGE TO BE PRINTED
C
      RN(1)=4.
      DO 50 I=2,11
50    RN(I)=RN(I-1)+4.
      WRITE (6,110) RN
      WRITE (6,130)
      RRN(1)=4
      DO 60 I=2,101
60    RRN(I)=RRN(I-1)+.4
      KK=5
      JJ=1
C
C         WRITE THE ARRAYS USED FOR PRINTER PLOT
C
      DO 70 I=1,21
      WRITE (6,120) (SIG(J),RRN(J),J=JJ,KK)
      KK=KK+5
      JJ=JJ+5
      IF (KK.GT.101) KK=101
70    CONTINUE
C
80    FORMAT (9X,10(9(1H-),1H+),1H-)
90    FORMAT (2X,F5.1,2H +,101A1,1H+)
100   FORMAT (8X,1H1,101A1,1H1)
110   FORMAT (1X,11(7X,F3.0),/,60X,9HRANGE  NM)
120   FORMAT (1H ,10F10.2)
130   FORMAT (1H1,5(20HSIGNAL  DB  RANGE NM))
      END


      SUBROUTINE MULTPTH (RNGE,REF,H1,ALTAC,ICKMP,DBGAIN,FREQ)
C
C          SUBROUTINE TO CALCULATE MULTIPATH EFFECTS FOR MATCH
C          REF AFFTC TD-75-3
C
      COMPLEX NN,RR,RT,REF
      ICKMP=0
      NN=REF
      TALT=ALTAC
C
C        POL = 1 FOR VERTICAL AND POL = 0 FOR HORIZONTAL POLARIZATION
C        VERTICAL IS ALWAYS USED FOR THIS PROGRAM
C
      POL=1
      RANGE=1.149*RNGE
C
C      CALCULATE DIST1 AND H2PRI
C
```

```
      CALL DIST (RANGE,H1,TALT,DIST1,ICKMP,H2PRI)
      IF (ICKMP.EQ.1.0) GO TO 40
      ARG2=H1/(5280.0*DIST1)
C
C       FIND ANGLE OF INCID/REFLEC
C
      SI=(ATAN(ARG2))
C
C       IF ANGLE OF REFLECTION GT .2 RADIAN DO NOT CALCULATE GAIN
C
      IF (SI.GT..2) GO TO 50
      RT=CSQRT(NN-COS(SI)**2)
C
C        FIND REFLEC COEF AND ANGLE
C
      IF (1.C-POL) 1C,10,20
10    RR=(NN*SIN(SI)-RT)/(NN*SIN(SI)+RT)
      GO TO 30
20    RR=(SIN(SI)-RT)/(SIN(SI)+RT)
C
C        DIVERGENCE IS CALCULATED
C
30    D=SQRT(1.0+((2.0*DIST1)*(RANGE-DIST1)**2)/(RANGE*H2PRI))
C
C        REFLECTION COEFFICIENT IS CALCULATED
C
      RMAG=SQRT(REAL(RR)**2+AIMAG(RR)**2)
      PHI=ATAN2(AIMAG(RR),REAL(RR))
      DIV=1.0/D
C
C        CALCULATE THETA
C
      H3=H1-DIST1**2/2.0
      THETA=(0.0001385*H3*H2PRI*FREQ)/57.3/RANGE
      ANGLE3=THETA-PHI
C
C         DB GAIN IS CALCULATED
C
      GAIN=1.0+(DIV*RMAG)**2+2.0*DIV*RMAG*COS(ANGLE3)
      DBGAIN=10*ALOG10(GAIN)
40    RETURN
50    ICKMP=1
      END
```

```
      SUBROUTINE DIST (RANGE,H1,TALT,DIST1,ICKMP,H2PRI)
C
C         SUBROUTINE TO CALCULATE DIST1 AND H2PRI
C
      DIST1=C.0
C
C         DH IS LINE OF SIGHT RANGE
C
      DH=1.414*(SQRT(H1)+SQRT(TALT))
      IF (DH.LT.RANGE) GO TO 70
      DO 10 I=1,200
      DIST1=0.1+DIST1
C
C         DIST1 IS THE DISTANCE FROM ANTENNA TO REFLECTIVE SURFACE
C
      IF (DIST1.GT.RANGE) GO TO 70
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 20
10    CONTINUE
20    DIST1=DIST1-.1
      DO 30 I=1,100
      DIST1=0.01+DIST1
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 40
30    CONTINUE
40    DIST1=DIST1-.01
      DO 50 I=1,100
      DIST1=0.001+DIST1
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 60
50    CONTINUE
60    RETURN
70    ICKMP=1.0
      END
```

```
      OVERLAY(MULT,3,0)
C
C         OVERLAY MULT PREDICTS THE MULTIPATH EFFECTS ON THE DATA
C
C         A PRINTER PLOT OF THE GAIN VS. RANGE IS PRINTED ALONG WITH
C        THE CORRESPONDING DATA FOR EACH CELL. REF AFFTC TD-75-3
C
      PROGRAM MULT
      COMPLEX NN,RR,RT
      DIMENSION AMTRX(100),MTRX(50,100)
      DIMENSION XMTRX(11),ALT(8),RNG(100),ELANG(100),REFD(100),DB(100)
```

```
C
C        PRINT FORMAT WILL BE 8 LINES PER INCH
C
      WRITE (6,120)
C
C         THE ALTITUDES ARE READ IN ; ADAP CARD NO. 8
C
      READ (5,140) ALT
      DO 5 I=1,8
      IF(ALT(I).EQ.0) GO TO 10
      NALT=I
5     CONTINUE
C
C         THE BEGINNING RANGE AND END RANGE, ANTENNA HEIGHT IN FEET,
C        THE FREQUENCY IN MHZ, POLARIZATION, PERMITTIVITY, AND
C        CONDUCTIVITY ARE READ IN
C
C         READ ADAP CARD NO. 9
C
10    READ (5,150) RANGE1,RANGE2,H1,FREQ,POL,E,S
      IF (EOF(5).NE.0.) GO TO 110
      XX=0.0
      YY=0.0
      ADD=(RANGE2-RANGE1)/10.0
C
C         LOAD THE RANGE ARRAY FOR PLOTTING ON THE X-AXIS OF THE PRINTER
C         PLOT
C
      DO 20 KK=1,11
      XMTRX(KK)=RANGE1+XX
20    XX=XX+ADD
C
C        FIND INDEX OF REFRACTION
C
      NN=CMPLX(E,-S*18000./FREQ)
C
C       PRODUCE PLOT AND PRINT DATA FOR EACH ALTITUDE
C
      DO 100 I=1,NALT
      DMIN=1000.
      DMAX=0.
      RANGE=RANGE1
      RANGE=1.149*RANGE
      TALT=ALT(I)
      DO 80 JJ=1,100
C
C       FIND CORRECT DIST 1
C
      CALL DDIST (RANGE,H1,TALT,DIST1,CHECK,H2PRI,DMIN,DMAX)
      RNG(JJ)=RANGE/1.149
      ELANG(JJ)=ATAN((ALT(I)-H1)/(RANGE*5280.))*57.4
      REFD(JJ)=DIST1/1.149
      IF (CHECK.EQ.1.0) GO TO 60
      ARG2=H1/(5280.0*DIST1)
C
C        FIND ANGLE OF INCID/REFLEC
C
      SI=(ATAN(ARG2))
      RT=CSQRT(NN-COS(SI)**2)
C
C        FIND REFLEC COEF AND ANGLE
C
      IF (1.0-POL) 30,30,40
C
C        REFLEC COEF FOR VERTICAL POL
C
30    RR=(NN*SIN(SI)-RT)/(NN*SIN(SI)+RT)
      GO TO 50
C
C        REFLEC COEF FOR HORIZONTAL POL
C
40    RR=(SIN(SI)-RT)/(SIN(SI)+RT)
50    D=SQRT(1.0+((2.0*DIST1)*(RANGE-DIST1)**2)/(RANGE*H2PRI))
      RMAG=SQRT(REAL(RR)**2+AIMAG(RR)**2)
      PHI=ATAN2(AIMAG(RR),REAL(RR))
      IF (SI.GT..2) GO TO 60
      DIV=1.0/D
C
C        CALCULATE THETA
C
      H3=H1-DIST1**2/2.0
      THETA=(0.0001385*H3*H2PRI*FREQ)/57.3/RANGE
      ANGLE3=THETA-PHI
C
C        CALCULATE GAIN DUE TO MULTIPATH EFFECTS AND LOAD IN THE ARRAY
C        AMTRX FOR PLOTTING
C
      GAIN=1.0+(DIV*RMAG)**2+2.0*DIV*RMAG*COS(ANGLE3)
      DBGAIN=10*ALOG10(GAIN)
      DB(JJ)=DBGAIN
      AMTRX(JJ)=GAIN
      GO TO 70
60    AMTRX(JJ)=0
      DB(JJ)=0.
70    CONTINUE
      RANGE=RANGE+(RANGE2-RANGE1)*1.149/100
80    CONTINUE
C
C        CALL PLOTTING ROUTINE THAT PRODUCES THE PRINTER PLOT
C
```

```
      CALL GNPLOT (AMTRX,MTRX,XMTRX,TALT)
      PRINT 160, RANGE1,RANGE2,H1,FREQ,POL,E,S
      DMIN=DMIN/1.149
      DMAX=DMAX/1.149
      PRINT 170, NN,DMIN,DMAX
      PRINT 180
      DO 90 M=1,10
      K1=1+10*(M-1)
      K2=K1+9
      PRINT 190, (RNG(K),K=K1,K2),(DB(JJ),JJ=K1,K2),(ELANG(J),J=K1,K2),(
     1REFD(L),L=K1,K2)
   90 CONTINUE
  100 CONTINUE
      GO TO 10
  110 STOP
C
  120 FORMAT (1HT)
  130 FORMAT (I2)
  140 FORMAT (10(F10.3))
  150 FORMAT (7F10.3,I2)
  160 FORMAT (1X,/,1X,20HDISTANCE INTERVAL NM,4X,18HANTENNA HEIGHT FT.,5
     1X,13HFREQUENCY MHZ,2X,13HPOL(0=H, 1=V),2X,12HPERMITTIVITY,2X,12HCO
     2NDUCTIVITY,/,1X,F6.0,1X,2HTO,1X,F6.0,13X,F5.1,15X,F8.2,5X,F8.2,12X
     3,F6.2,4X,F7.5)
  170 FORMAT (1X,/,3X,38HCALCULATED INDEX OF REFRACTION SQUARED,4X,60HDI
     1STANCE FR. ANTENNA TO REFLECTION PT. NM. MINIMUM   MAXIMUM,/,13X,F
     29.4,1X,1H ,1X,F9.4,1X,1HJ,52X,F8.2,3X,F8.2)
  180 FORMAT (1H1,10F10.5)
  190 FORMAT (1H ,18HRANGE (NM)         ,10F11.2,/,1X,18HGAIN (DB)
     1  ,10F11.2,/,1X,18HELEV. ANG (DEG)    ,10F11.2,/,1X,18HREF. DIST. (
     2NM )   ,10F11.2,/)
      END


      SUBROUTINE DDIST (RANGE,H1,TALT,DIST1,CHECK,H2PRI,DMIN,DMAX)
C
C        SUBROUTINE TO CALCULATE DIST1 AND H2PRI
C
      CHECK=0.0
      DIST1=0.0
C
C        DH IS LINE OF SIGHT RANGE
C
      DH=1.414*(SQRT(H1)+SQRT(TALT))
      IF (DH.LT.RANGE) GO TO 70
      DO 10 I=1,200
C
C       DIST1 IS THE DISTANCE FROM THE ANTENNA TO THE REFLECTING SURFACE
C
      DIST1=0.1+DIST1
      IF (DIST1.GT.RANGE) GO TO 70
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 20
   10 CONTINUE
   20 DIST1=DIST1-.1
      DO 30 I=1,100
      DIST1=0.01+DIST1
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 40
   30 CONTINUE
   40 DIST1=DIST1-.01
      DO 50 I=1,100
      DIST1=0.001+DIST1
      H2PRI=H1*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 60
   50 CONTINUE
   60 CONTINUE
      DMIN=AMIN1(DMIN,DIST1)
      DMAX=AMAX1(DMAX,DIST1)
      RETURN
   70 CHECK=1.0
      END


      SUBROUTINE GNPLOT (AMTRX,MTRX,XMTRX,TALT)
C
C          SUBROUTINE TO PRINT A PLOT OF THE GAIN DUE TO MULTIPATH EFFECT
C          VS. THE RANGE
C
      INTEGER A(5)
      DIMENSION AMTRX(100),MTRX(50,100),XMTRX(11)
      A1=7.0
      A2=6.0
      A3=4.8
      A4=3.0
      A5=0.
      DO 10 I=1,5
      A(I)=I
   10 CONTINUE
      LL=10*LL-10
      IF (LL.EQ.0) LL=1
      DO 20 M=1,50
```

```
      DO 20 N=1,100
      MTRX(M,N)=10H
20    CONTINUE
C
C        LOAD THE PLOTTING ARRAY
C
      DO 30 J=1,100
      IF (AMTRX(J).GT.50.0) AMTRX(J)=50.0
      I=(5C.C*AMTRX(J)/5.0)+.5
      IF (I.EQ.0.) GO TO 30
      MTRX(I,J)=1H.
30    CONTINUE
      PRINT 50, TALT
      DO 40 I=1,50
      K=51-I
      IF (K.NE.50.AND.K.NE.40.AND.K.NE.30.AND.K.NE.20.AND.K.NE.10) PRINT
     1 70, (MTRX(K,J),J=1,100)
      M=K/10
      IF (K.EQ.50.) PRINT 60, A(M),(MTRX(K,J),J=1,100),A1
      IF (K.EQ.40.) PRINT 60, A(M),(MTRX(K,J),J=1,100),A2
      IF (K.EQ.30.) PRINT 60, A(M),(MTRX(K,J),J=1,100),A3
      IF (K.EQ.20.) PRINT 60, A(M),(MTRX(K,J),J=1,100),A4
      IF (K.EQ.10.) PRINT 60, A(M),(MTRX(K,J),J=1,100),A5
40    CONTINUE
      PRINT 80
      PRINT 90, XMTRX
      RETURN
C
50    FORMAT(1H1,50X,31HPOWER GAIN PLOT AT ALTITUDE OF ,/,60X,F10.3, 10H
     1  FT. AGL.,//,3X,10HPOWER GAIN,110X,6HDBGAIN,/,17X,1H1,10(1H+,9(1H
     2-)),1H+)
60    FORMAT (1H ,10X,I1,5X,1H+,100A1,1H+,3X,F3.1)
70    FORMAT (1X,16X,1H1,100A1,1H1)
80    FORMAT (1X,10X,1H0,5X,1H1,10(1H+,9(1H-)),1H+)
90    FORMAT (12X,11(5X,F5.1),/,63X,8HRANGE NM)
      END
```

```
      OVERLAY(RDMERGE,4,0)
C
C        OVERLAY THAT MERGES UP TO THREE RADAR TAPES TOGETHER
C
      PROGRAM RDMERGE
      DIMENSION I2(2),T2(2),T4(6)
C
C        READ ADAP CARD NO. 2
C
      READ (5,50) NUM
      WRITE (6,60) NUM
      NN=11
      DO 40 I=1,NUM
10    READ (NN) I1,T1,I2,T2,I3,T4
      IF (EOF(NN)) 30,20
20    IF (I1.NE.101) GO TO 10
      WRITE (10) I1,T1,I2,T2,I3,T4
      IHR=I2(1)
      IMIN=I2(2)
      GO TO 10
30    NN=NN+1
40    CONTINUE
      WRITE (6,70) IHR,IMIN
      STOP
C
50    FORMAT (I10)
60    FORMAT (1H ,I3,29H  RADAR TAPES WILL BE MERGED )
70    FORMAT (24H   LAST TIME MERGED WAS ,I4,3H HR,I4,4H MIN)
      END
```

APPENDIX G

ADAP SOURCE LISTING

```
      PROGRAM ARPMP(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
     1TAPE12)
C
C     THIS PROGRAM CALCULATES A/C ANTENNA RADIATION PATTERNS (IN ERP DBW
C
      COMMON ITYPE,NUMSR,      IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HDZ,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      DIMENSION ICHR(8),SLOSS(20),RGAIN(20),IHEAD(8),PERM(20),COND(20)
      COMPLEX REF
      IXX=1
      DAYS=0.0
      DAYR=0.0
      ROSTT=0.0
      ICK=0
      REWIND 10
      REWIND 11
      NUMD=0
      WRITE (6,290)
C     ****************************************************************
C                   READ INPUT CARDS    ******************************
C     ****************************************************************
C
C          READ HEADING RECORD (ARPMP CARD # 1)
C
      READ (5,420) IHEAD
      WRITE (6,420) IHEAD
C
C          READ ARPMP CARD # 2
C
      READ (5,300) IRADAR,IPCAL,IMULT,NTYPP,NUMSR,ISTDAT,NUMRNG,ALTAC
      WRITE (6,310) NTYPP,NUMSR,IRADAR,NUMRNG,ALTAC,IPCAL,ISTDAT,IMULT
C
C          READ ARPMP CARD # 3
C
      READ (5,320) (FREQ(I),SLOSS(I),RGAIN(I),I=1,NUMSR)
      WRITE (6,330) (I,FREQ(I),SLOSS(I),RGAIN(I),I=1,NUMSR)
      IF (IMULT.NE.1HY) GO TO 120
C
C         IF MULTIPATH OPTION USED --READ ARPMP CARD # 4
C
      READ (5,320) (ANTHT(I),PERM(I),COND(I),I=1,NUMSR)
      DO 110 I=1,NUMSR
C
C         CALCULATES REFLECTIVITY
C
  110 REF(I)=CMPLX(PERM(I),-COND(I)*18000./FREQ(I))
      WRITE (6,340) (I,ANTHT(I),PERM(I),COND(I),REF(I),I=1,NUMSR)
  120 IF (IRADAR.NE.1HN) GO TO 140
C
C          IF NO RADAR TAPE -- READ RANGE AND CORRESPONDING TIMES, ARPMP
C           CARD # 5
C
      READ (5,350) (RDRNG(1,I),IDATA(6*(I-1)+1),IDATA(6*(I-1)+2),IDATA(6
     1*(I-1)+3),IDATA(6*(I-1)+4),IDATA(6*(I-1)+5),IDATA(6*(I-1)+6),I=1,N
     2UMRNG)
C
C          CALCULATES TOTAL SEC OF RANGE TIMES
C
      DO 130 I=1,NUMRNG
      RDRNG(2,I)=IDATA(6*(I-1)+1)*3600.+IDATA(6*(I-1)+2)*60.+IDATA(6*(I-
     11)+3)
  130 RDRNG(3,I)=IDATA(6*(I-1)+4)*3600.+IDATA(6*(I-1)+5)*60.+IDATA(6*(I-
     11)+6)
      WRITE (6,360) (IDATA(6*(I-1)+1),IDATA(6*(I-1)+2),IDATA(6*(I-1)+3),
     1IDATA(6*(I-1)+4),IDATA(6*(I-1)+5),IDATA(6*(I-1)+6),I=1,NUMRNG)
C
C            CALCULATES LOSSES TO BE USED IN ERP CALCULATION
C
  140 DO 150 I=1,NUMSR
      DELDB(I)=SLOSS(I)-RGAIN(I)+37.8+20*ALOG10(FREQ(I))
  150 CONTINUE
      DO 160 I=1,NUMSR
  160 IDATAG(I)=0
C     ****************************************************************
C         READ IN THE HEADING RECORD ON SIGNAL TAPE   ****************
C     ****************************************************************
  170 BUFFER IN (10,1) (IDATA(1),IDATA(1))
      IF (UNIT(10)) 180,250,180
  180 CONTINUE
      IK=II
      II=IWRD(1)
      IK=II
      II=AND(SHIFT(II,-13),7B)
C
C          IF II EQUALS 4 -- HEADING RECORD FOUND
C
      IF (II.EQ.4) GO TO 190
C
C          IF HEADING RECORD NOT FOUND BY SECOND TRY -- END RUN
C
      IF (ICK.EQ.1) GO TO 270
      ICK=1
      REWIND 10
      GO TO 170
C     ****************************************************************
C         READ IN THE TIME CALIBRATION RECORD  ***********************
C     ****************************************************************
```

```
190   BUFFER IN (10,1) (IDATA(1),IDATA(12))
      IF (UNIT(10)) 200,250,200
200   CONTINUE
      II=IWRD(1)
      IK=II
      II=AND(SHIFT(II,-13),78)
C
C          IF II EQUALS 6-- TIME CAL RECORD FOUND -- SET TIME TAG
C
      IF (II.NE.6) GO TO 260
      ITTAG=IWRD(43)
      WRITE (6,370)
      DO 220 I=1,NUMSR
C     ****************************************************************
C        READ DATA CAL RECORD FOR EACH SOURCE    ************************
C     ****************************************************************
      BUFFER IN (10,1) (IDATA(1),IDATA(12))
      IF (UNIT(10)) 210,250,210
210   CONTINUE
      IK=IWRD(1)
      KK=I
      II=IK
      II=AND(SHIFT(II,-13),78)
C
C        IF II EQUALS 6 SET DATA TAG
C
      IF (II.NE.6) GO TO 280
      IDATAG(I)=IWRD(43)
C
C.       CONVERT 80 EBCDIC CHARACTERS TO CDC CODE
C
      CALL IDFUN (ICHR)
      WRITE (6,380) I,ICHR
220   CONTINUE
C     ***************************************************************
C        CALL SUBROUTINE CAL TO CREATE SIGNAL CALIBRATION ARRAY *******
C     ****************************************************************
230   CALL CAL (IPCAL)
      REWIND 10
      NUMD=0
      DAYS=0
      DO 240 II=1,NTYPP
C     ****************************************************************
C          CALL SUBROUTINE READD TO START PROCESSING DATA    ************
C     ****************************************************************
      CALL READD
240   CONTINUE
      END FILE 12
      REWIND 10
      REWIND 11
      REWIND 12
      STOP
250   WRITE(6,430)
      STOP
260   WRITE (6,390)
      STOP
270   WRITE (6,400)
      STOP
280   WRITE (6,410) KK,IK
      CALL SETTIME
      DO 285 J=1,NUMSR
285   IDATAG(J)=1
      GO TO 230
C
290   FORMAT (1H1,35X,42HAIRCRAFT ANTENNA RADIATION PATTERN PROGRAM)
300   FORMAT (3A1,I7,3I10,F10.3)
310   FORMAT (1H0,44HTHE NUMBER OF DIFFERENT FLIGHT PATTERNS ARE ,I4,/,1
     1H ,22HNUMBER OF SOURCES ARE ,I4,10X,8HRADAR = ,A1,22H   NUMBER OF
     2RANGES = ,I4,11H  AC ALT = ,F10.2,/,23H PRE AND POST  CALS  = ,A1
     3,13H START DAY = ,I4,/,31H MULTIPATH SIGNAL ELIMINATED = ,A1)
320   FORMAT (6F10.3)
330   FORMAT (1H ,14HSOURCE NUMBER ,I4,12H FREQUENCY =,F8.3,,23HMHZ   SY
     1STEM  LOSSES = ,F5.2,20H DB RECEIVER GAIN = ,F5.2,3H DB)
340   FORMAT (15H SOURCE NUMBER ,I2,18H ANTENNA HEIGHT = ,F8.3,16H PERMI
     1TTIVITY = ,F8.3,16H CONDUCTIVITY = ,F8.3,/   ,31H THE CALCULATED R
     2EFLECTIVITY = ,2F10.3,2H J)
350   FORMAT (4(F3.0,1X,3I2,4X,3I2))
360   FORMAT (19H TIME OVER SITE =  ,3I2,9H TIME AT ,F6.1,6H NM = ,3I2)
370   FORMAT (1H0,3HTAG,4X,6HSOURCE)
380   FORMAT (1H ,I3,4X,8A10)
390   FORMAT (1X,25HTIME CAL RECORD NOT FOUND)
400   FORMAT (1X,24HHEADING RECORD NOT FOUND)
410   FORMAT (1H ,6HSOURCE,I4,20HCAL RECORD NOT FOUND,O8)
420   FORMAT (8A10)
430   FORMAT(" END OF FILE ENCOUNTERED ON SIGNAL TAPE --TAPE10-- NO DATA
     1RECORD FOUND")
      END
```

```
      SUBROUTINE READD
C     *      THIS SUBROUTINE CREATES THE FINAL OUTPUT DATA BY  *********
C     *        CALLING RADAR AND SIGNAL   *******************************
      COMMON ITYPE,NUMSR,     IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,RDSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      DIMENSION IHR1(90),MIN1(90),ISEC1(90),IHR2(90),MIN2(90),ISEC2(90),
```

```
     1   VDAT(482),SIG(20),SMAX(20),SMIN(20)
C     ****************************************************************
C        READ IN THE HEADING TYPE, THE NUMBER OF HEADINGS  **************
C          THE ROLL ANGLE, THE PITCH ANGLE--ARPMP CARD #  8  ************
C     ****************************************************************
      READ(5,180) IHDTYP,NUMHD,IROLL,IPTCH,IHST,IMST,ISST,IHSP,IMSP,ISSP
      IF(IHDTYP.LT.1.OR.IHDTYP.GT.3) GO TO 175
      WRITE (6,190) IHDTYP,NUMHD,IROLL,IPTCH
      IF(IHDTYP.EQ.3) WRITE(6,195) IHST,IMST,ISST,IHSP,IMSP,ISSP
C     ****************************************************************
C        READ IN THE HEADING AND THE CORRESPONDING TIME INTERVALS *******
C     *************      ARPMP CARD #  9  *****************************
C     ****************************************************************
      READ (5,200) ((IHED(I),IHR1(I),MIN1(I),ISEC1(I),IHR2(I),MIN2(I),IS
     1EC2(I)),I=1,NUMHD)
      IF(IHDTYP.EQ.1) WRITE(6,210) ((IHED(I),IHR1(I),MIN1(I),ISEC1(I),
     1IHR2(I),MIN2(I),ISEC2(I)),I=1,NUMHD)
      IF(IHDTYP.NE.1) WRITE(6,215) ((IHED(I),IHR1(I),MIN1(I),ISEC1(I)),
     1I=1,NUMHD)
      TRIM=0.
      DO 10 I=1,NUMHD
      TIM1(I)=IHR1(I)*3600+MIN1(I)*60+ISEC1(I)
      IF(TIM1(I).LT.TRIM) GO TO 177
      TRIM=TIM1(I)
   10 TIM2(I)=IHR2(I)*3600+MIN2(I)*60+ISEC2(I)
      TRIM=0.
C     ****************************************************************
C        FIND DATA FOR ALL TIME INTERVALS   ****************************
C     ****************************************************************
      DO 20 MI=1,NUMSR
      SMAX(MI)=-9999.
   20 SMIN(MI)=9999.
      NN=1
      DO 30 J=1,482
      VDAT(J)=0.
   30 CONTINUE
C
C        IF DISCRETE DATA POINTS SET NN TO NUMBER OF POINTS (NUMHD)
C
      IF (IHDTYP.NE.3) GO TO 40
C
C       IF CONTINUOUS DATA SAMPLES SET NN TO NUMBER OF .5 SEC INTERVLS
C
      SP=IHSP*3600+IMSP*60+ISSP
      ST=IHST*3600+IMST*60+ISST
      NN=(SP-ST)*2.0
      TIM=ST-.5
C     ****************************************************************
C        SETS NN POINTS OF DATA FOR THE INTERVAL  **********************
C     ****************************************************************
   40 IF (IHDTYP.EQ.2) NN=NUMHD
      IF (IHDTYP.NE.1) GO TO 45
      NN=(TIM2(NUMHD)-TIM1(1))*2.0
      TIM=TIM1(1)-.5
   45 DO 160 J=1,NN
      IF (IHDTYP.EQ.2) GO TO 90
C
C      CONTINOUS DATA
C
      TIM=TIM+.5
      IF (IHDTYP.NE.1) GO TO 70
      DO 50 I=1,NUMHD
      IF (TIM.GE.TIM1(I).AND.TIM.LE.TIM2(I)) GO TO 70
   50 CONTINUE
      DO 60 I=1,NUMHD
      IF (TIM.LE.TIM2(I)) GO TO 65
   60 CONTINUE
      GO TO 165
   65 TIM=TIM1(I)
C     ****************************************************************
C        GET HALF OF A SECOND OF AVERAGED DATA  ************************
C     ****************************************************************
   70 CALL RADAR (ASP,DEP,TIM,TRIM,RNG,IROLL,IPTCH,RNGXY,IRCK)
      IF (IRCK.EQ.1) GO TO 160
      CALL SIGNAL (TIM,SIG)
      DO 80 LM=1,NUMSR
      IF (SIG(LM).EQ.0) GO TO 80
      ICKMP=0
      DBGAIN=0.
C
C      CALL MULTPTH IF OPTION IS SELECTED
C
      IF (IMULT.EQ.IHY) CALL MULTPTH (RNGXY,LM,ICKMP,DBGAIN)
      IF(ICKMP.EQ.1) SIG(LM)=0.
      IF (ICKMP.EQ.1) GO TO 80
C
C     CALCULATE SIGNAL IN DBW
C
      SIG(LM)=VCAL(SIG(LM),LM)+DELDB(LM)+20*ALOG10(RNG)
      SIG(LM)=SIG(LM)-30.-DBGAIN
      SMAX(LM)=AMAX1(SMAX(LM),SIG(LM))
      SMIN(LM)=AMIN1(SMIN(LM),SIG(LM))
   80 CONTINUE
      GO TO 130
C
C       DISCRETE DATA SAMPLES GET AVERAGED DATA FROM TIM-2.0 TO TIM
C
   90 HD2=IHED(J)
      DO 100 K=1,NUMSR
      SIG(K)=0.
```

```
      TIM2(K)=0.
100   CONTINUE
      TIM=TIM1(J)
      CALL RADAR (ASP,DEP,TIM,TRIM,RNG,IROLL,IPTCH,RNGXY,IRCK)
      TIM=TIM-2.5
      DO 110 JJ=1,4
      TIM=TIM+.5
      CALL SIGNAL (TIM,SIG)
      DO 110 K=1,NUMSR
      TIM2(K)=TIM2(K)+SIG(K)
110   CONTINUE
C
C             DATA AVERAGED FOR 2 SECONDS   ************************
C
      DO 120 K=1,NUMSR
      IF (TIM2(K).EQ.0.0) GO TO 120
      TIM2(K)=TIM2(K)/4.0
      ICKMP=0
      DBGAIN=0.
C
C     CALL MULTPTH IF OPTION SELECTED
C
      IF (IMULT.EQ.1HY) CALL MULTPTH (RNGXY,K,ICKMP,DBGAIN)
      IF(ICKMP.EQ.1) SIG(K)=0.
      IF (ICKMP.EQ.1) GO TO 120
C
C     CALCULATE SIGNAL IN DBW
C
      SIG(K)=VCAL(TIM2(K),K)+DELDB(K)+20*ALOG10(RNG)
      SIG(K)=SIG(K)-30.-DBGAIN
      SMAX(K)=AMAX1(SMAX(K),SIG(K))
      SMIN(K)=AMIN1(SMIN(K),SIG(K))
120   CONTINUE
C     ***********************************************************
C       CREATE THE OUTPUT ARRAY   VDAT  ****************************
C     ***********************************************************
130   DO 150 K=1,NUMSR
      IF (SIG(K).EQ.0.) GO TO 150
C
C     PLACE NON-ZERO DATA IN OUTPUT ARRAY
C
      VDAT(MM)=K
      VDAT(MM+1)=SIG(K)
      VDAT(MM+2)=DEP
      VDAT(MM+3)=ASP
      VDAT(MM+4)=RNGXY
      VDAT(MM+5)=TIM
      MM=MM+6
      IF (J.EQ.NN) VDAT(482)=1
      IF (MM.LT.480) GO TO 150
      VDAT(481)=480
      WRITE (12) VDAT
      WRITE (6,220)
      WRITE (6,230) VDAT
      MM=1
      DO 140 L=1,482
140   VDAT(L)=0.
150   CONTINUE
160   CONTINUE
165   IF (MM.EQ.1) GO TO 170
      VDAT(481)=MM-1
      VDAT(482)=1
      WRITE (12) VDAT
      WRITE (6,220)
      WRITE (6,230) VDAT
      WRITE (6,240) (MI,SMIN(MI),SMAX(MI),MI=1,NUMSR)
170   CONTINUE
       RETURN
175    WRITE(6,250) IHDTYP
      STOP
177   WRITE(6,260)I,IHR1(I),MIN1(I),ISEC1(I),IHR1(I-1),MIN1(I-1),
     1ISEC1(I-1)
      STOP
C
180   FORMAT (4I10,2(4X,3I2))
190   FORMAT (1H1,20HTHE HEADING TYPE IS ,I2,
     A "  (1=FLYBY,RADIAL, 2=CLOVERLEAF,PLOYGON,3=ORBITS)",/,1X,
     B "THE NUMBER OF HEA  NGS ARE",
     1  1X,I2,/,1X,18HTHE ROLL ANGLE IS ,1X,I3,/,   " THE PITCH ANGLE IS
     2",1X,I2)
195   FORMAT(1X," START TIME IS ",I2," HRS ",I2," MINS ",I2," SECS",
     1"  STOP TIME IS ",I2," HRS ",I2," MINS ",I2," SECS")
200   FORMAT (4(I3,1X,3I2,4X,3I2))
210   FORMAT(1H0,"THE MAGNETIC HEADING IS ",I4,  /,1X,36HTHE CORRESPONDI
     1NG   TIME INTERVAL IS,1X,I2,1X,3HHRS,1X,I2,1X,4HMINS,1X,I2,1X,4HSE
     2CS,10X,2HTO,10X,I2,1X,3HHRS,1X,I2,1X,4HMINS,1X,I2,1X,4HSECS)
215   FORMAT(1H0,"THE MAGNETIC HEADING IS ",I4,  /," THE CORRESPONDING T
     1IME IS ",I2," HRS ",I2," MINS ",I2," SECS")
220   FORMAT (1H1,41HTHE DATA ARRAY TO BE USED BY ADAP IS ----,/,2X,2(60
     1H   SOURCE   SIGNAL  DEP ANGLE  ASP ANGLE   RANGE     TIME     ),/
     2,2X,2(13X,5H(DBW),4X,5H(DEG),6X,5H(DEG),6X,4H(NM),1X,11H(TOTAL SEC
     3)),//)
230   FORMAT (1H ,12F10.3)
240   FORMAT (1H ,3(40H SOURCE  NUMBER   MIN SIGNAL  MAX SIGNAL),/,4X,7(
     13(4X,I3,7X,F10.3,2X,F10.3,5X),/))
250   FORMAT(" ILLEGAL HEADING TYPE ",I10)
260   FORMAT(" ENTRY ",I3," IN THE HEADING ARRAY HAS A START TIME ",
     13I2," WHICH IS LESS THEN THE PRECEDING START TIME ",3I2)
      END
```

```
      SUBROUTINE SIGNAL (TIME,SIG)
C     ****************************************************************
C          THIS SUBROUTINE RETURNS THE ARRAY SIG WITH AVERAGED *********
C          DATA FOR EACH SOURCE FOR THE TIME INTERVAL--TIME-.5 TO TIME *
C     ****************************************************************
      COMMON ITYPE,NUMSR,      IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(2^),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      DIMENSION SIG(20),ISIG(20),NSIG(20)
      ICNT=0
      IF (NUMD.EQ.0) TLAST=1000000.
      IF (NUMD.EQ.0) GO TO 30
C
C          IF TIME IS LE END TIME OF DTIM ARRAY--DO NOT READ DATA
C
10    IF (TIME.LE.DTIM(NUMD,2)) GO TO 50
C     ****************************************************************
C       BUFFER IN A DATA RECORD INTO IDATA  ***************************
C     ****************************************************************
20    TLAST=DTIM(NUMD,2)
30    BUFFER IN (10,1) (IDATA(1),IDATA(512))
      IF (UNIT(10)) 40,220,40
40    CONTINUE
C
C         IF MORE THAN 100 BACKSPACES--END RUN
C
      IF (ICNT.GT.100) GO TO 230
C
C         IF STATUS WORD NE.0 -- READ NEW RECORD
C
      IF (IWRD(3).NE.0) GO TO 30
C     ****************************************************************
C      CALL SUBROUTINE SETTIME TO SET UP THE TIME ARRAY DTIM  *********
C     ****************************************************************
      CALL SETTIME
      GO TO 10
C
C         IF TIME GE START TIME IN ARRAY DTIM -- PROCESS DATA
C
50    IF (TIME.GE.DTIM(1,2)-.5) GO TO 80
C
C         IF TIME GT END TIME OF LAST RECORD AND LT START TIME
C         OF THIS RECORD--- THE TIME WAS NOT FOUND
C
      IF (TIME.GT.TLAST) GO TO 70
C
C         IF TIME LT END TIME OF LAST RECORD -- BACKSPACE TAPE 10
C
      DO 6C I=1,2
      BACKSPACE 10
60    CONTINUE
      ICNT=ICNT+1
      GO TO 20
70    WRITE (6,240) TIME,TLAST,DTIM(1,2)
80    IF=C
      IL=C
      NEXT=0
      DO 100 I=1,NUMD
C     ****************************************************************
C      FIND INDEX INTO DTIM FOR TIME INTERVAL   **********************
C     ****************************************************************
      IF (TIME.GE.DTIM(I,2).OR.IF.NE.0) GO TO 90
      IF=DTIM(I,1)
90    IF (TIME+.49.GT.DTIM(I,2)) GO TO 100
      IL=DTIM(I-1,1)
      IF (I.EQ.1) IL=DTIM(1,1)
      GO TO 110
100   CONTINUE
      NEXT=1
110   DO 120 I=1,NUMSR
      ISIG(I)=0
120   NSIG(I)=0
C     ****************************************************************
C     IF,IL -- FIRST AND LAST INDEX IN INTERVAL   *********************
C     ****************************************************************
130   J=IF
      K=IL
      IF (K.EQ.0) K=IWRD(2)
      IF (K.GT.1920) K=1920
      IF (J.LT.5) J=5
      DO 150 I=J,K,2
      DO 140 L=1,NUMSR
      IF (IWRD(I).NE.IDATAG(L)) GO TO 140
      ISIG(L)=ISIG(L)+IWRD(I-1)
      NSIG(L)=NSIG(L)+1
140   CONTINUE
150   CONTINUE
C
C        IF NEXT NE. 0 --- END TIME NOT FOUND -- READ NEW RECORD
C
      IF (NEXT.EQ.0) GO TO 200
      NEXT=0
      IF=DTIM(1,1)
C     ****************************************************************
C       BUFFER IN A DATA RECORD INTO IDATA  ***************************
C     ****************************************************************
      TLAST=DTIM(NUMD,2)
```

```
160   BUFFER IN (10,1) (IDATA(1),IDATA(512))
      IF (UNIT(10)) 170,220,170
170   CONTINUE
      IF (IWRD(3).NE.0) GO TO 160
C     ****************************************************************
C         CALL SUBROUTINE SETTIME TO SET UP THE TIME ARRAY DTIM  *******
C     ****************************************************************
      CALL SETTIME
      DO 180 I=1,NUMD
      IF (TIME+.49.GT.DTIM(I,2)) GO TO 180
      IL=DTIM(I-1,1)
      IF (I.EQ.1) IL=DTIM(1,1)
      GO TO 190
180   CONTINUE
      NEXT=1
190   GO TO 130
C
C        SET AVERAGED SIG ARRAY
C
200   DO 210 I=1,NUMSR
      IF (NSIG(I).EQ.0) GO TO 210
      ISIG(I)=FLOAT(ISIG(I))/FLOAT(NSIG(I))+.5
210   SIG(I)=ISIG(I)
      RETURN
220   WRITE(6,250)TLAST
      STOP
230   WRITE (6,260) TIME,DTIM(1,2),IDAY
      STOP
C
240   FORMAT (6H TIME ,F10.3,27H NOT FOUND NO DATA BETWEEN ,F10.3,5H AND
     1 ,F10.3)
250   FORMAT(" END OF FILE ENCOUNTERED - TAPE10 - LAST TIME  FOUND WAS",
     1 F10.3)
260   FORMAT (6H  TIME,F10.3,26H NOT FOUND FIRST TIME IS  ,F10.3,7H DAY
     1= ,I10)
      END


      SUBROUTINE RADAR (ASP,DEP,STMSEC,ETMSEC,RNG,IROLL,IPTCH,RNGXY,IRCK
     1)
C     ***************************************************************
C          THIS SUBROUTINE RETURNS THE A/C DEPRESSION ANGLE,ASPECT ***
C          ANGLE,SLANT RANGE, AND HORIZONTAL RANGE AT TIME STMSEC ****
C     ***************************************************************
      COMMON ITYPE,NUMSR,       IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      DIMENSION SUMV(6),DATA(6)
      IRCK=0
C
C        IF NO RADAR TAPE -- GO TO 200
C
      IF (IRADAR.EQ.1HN) GO TO 200
      DO 10 I=1,6
10    SUMV(I)=0.0
      AN=0.
      ROLL=IROLL
      IF (ETMSEC.NE.0.) GO TO 30
C     ****************************************************************
C       READ THE RADAR TAPE (TAPE11)    ******************************
C     ****************************************************************
20    READ (11) IWD,TTMS,IHR,IMIN,TMSEC,ETMSEC,ISTWD,(DATA(I),I=1,6)
      IF (EOF(11).NE.0.) GO TO 190
C
C       USE ONLY DATA RECORDS WHERE IWD EQUALS 101
C
30    IF (IWD.NE.101) GO TO 20
      IF (DAYR.EQ.1.0) GO TO 40
      IF (ROSTT.EQ.0.0) ROSTT=TTMS
      IF (ROSTT.GT.TTMS) DAYR=1.0
40    TTMS=TTMS+DAYR*24*3600
C
C        IF STATUS WORD NOT VALID -- READ NEW RECORD
C
      IF (ISTWD.EQ.10H          /) GO TO 50
      GO TO 20
50    IF (TTMS.LT.STMSEC) GO TO 20
C
C        IF END OF .5 SEC DATA REACHED -- PROCESS DATA
C
      IF (TTMS.GE.(STMSEC+.5)) GO TO 80
60    DO 70 I=1,6
70    SUMV(I)=SUMV(I)+DATA(I)
      AN=AN+1
      GO TO 20
C
C        IF NO DATA FOUND -- GET NEW RECORD
C
80    IF (AN.EQ.0.) GO TO 60
      DO 85 I=1,6
85    DATA(I)=SUMV(I)/AN
      RNG=SQRT(DATA(1)**2+DATA(2)**2+DATA(3)**2)/6076.
      RNGXY=SQRT(DATA(1)**2+DATA(2)**2)/6076.
      IF (IHDTYP.GT.3) GO TO 170
      HEAD=HD2
C
```

```
C         FOR DISCRETE POINTS (CLOVER LEAFS,POLYGON FLIGHTS) GO TO 160
C
      IF (IHDTYP.EQ.2) GO TO 160
C
C         FOR ORBIT FLIGHTS GO TO STATEMENT 110
C
      IF (IHDTYP.EQ.3) GO TO 110
C     ****************************************************************
C       THE HEADING IS READ IN IN TIME INTERVALS    ********************
C     ****************************************************************
C
C         FOR FLYBYS AND RADIALS START HERE
C
      DO 100 I=1,NUMHD
C
C         FIND HEADING FOR TIME STMSEC
C
      IF (STMSEC.GE.TIM1(I).AND.STMSEC.LE.TIM2(I)) GO TO 90
      GO TO 100
90    HEAD=IHED(I)
      GO TO 160
100   CONTINUE
C
C         IF TIME INTERVAL NOT FOUND GO TO STATEMENT 180
C
      GO TO 180
C
C         ORBIT FLIGHTS
C
110   DO 120 I=1,NUMHD
C
C         II = UPPER INTERVAL OF TIME
C
      II=I
      IF (TIM1(I).GT.STMSEC) GO TO 130
120   CONTINUE
      GO TO 180
130   H1=IHED(II-1)
      H2=IHED(II)
      DELH=ABS(H1-H2)
      IF (DELH.LT.200) GO TO 150
      IF (H1.GT.180.) GO TO 140
      H1=H1+360.
      GO TO 150
C
C         DETERMINE HEADING BY LINEAR INTERPOLATION OF TIME
C
140   H2=H2+360
150   HEAD=(H2-H1)*(STMSEC-TIM1(II-1))/(TIM1(II)-TIM1(II-1))+H1
      IF (HEAD.GT.360.) HEAD=HEAD-360.
      IF (HEAD.LT.0.) HEAD=HEAD+360.
C
C        SETUP DATA TO CALL SUBROUTINE PAMS
C
160   TASP=ATAN2(DATA(2),DATA(1))*57.3
      TDEP=ATAN(DATA(3)/(RNGXY*6076.))*57.3
      IF (TASP.LT.0.) TASP=TASP+360.
      RNGM=RNG*1852.
      PTCH=IPTCH
      ALTAC=DATA(3)
C
C        CALL PAMS FOR ASPECT ANGLE AND DEPRESSION ANGLE
C
      CALL PAMS (ASP,DEP,RNGM,TASP,TDEP,HEAD,PTCH,ROLL)
      RETURN
170   WRITE (6,240) IHDTYP
      STOP
180   WRITE (6,250) STMSEC,IHDTYP
      IRCK=1
      RETURN
190   WRITE (6,260) TTMS
      STOP
200   ASP=0.
      DEP=0.
      ETMSEC=0.
      DO 220 I=1,NUMRNG
      IN=I
      IF (RDRNG(2,I).GT.RDRNG(3,I)) GO TO 210
      IF (STMSEC.GE.RDRNG(2,I).AND.STMSEC.LE.RDRNG(3,I)) GO TO 230
      GO TO 220
210   IF (STMSEC.LE.RDRNG(2,I).AND.STMSEC.GE.RDRNG(3,I)) GO TO 230
220   CONTINUE
230   RNGXY=RDRNG(1,IN)*(STMSEC-RDRNG(2,IN))/(RDRNG(3,IN)-RDRNG(2,IN))
      RNG=SQRT(RNGXY**2+ALTAC/6076.**2)
C
240   FORMAT (1X,24H  ILLEGAL HEADING  TYPE ,I2)
250   FORMAT (1X,4HTIME,F8.1,24H NOT IN HEADING INTERVAL,17HFOR HEADING
     1TYPE ,I2)
260   FORMAT (1X,66HEND OF FILE ENCOUNTERED ON RADAR TAPE--LAST TIME
     1     FOUND WAS ,F10.3)
      END


      SUBROUTINE CAL (IPCAL)
C     ****************************************************************
C         THIS SUBROUTINE SETS UP THE SIGNAL CALIBRATION ARRAYS ********
C         CALMV AND CALSG          ************************************
C     ****************************************************************
      COMMON ITYPE,NUMSR,     IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
```

```
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,RDSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      DIMENSION IHR(50),IMIN(50),ISEC(50),NSRID(20),SIG(20),TPSG(2,100)
      INTEGER CALSE
      IXX=1
C
C        IF PRE AND POST CALS --  SET IXX = 2
C
      IF (IPCAL.EQ.1HY) IXX=2
      DO 10 I=1,100
      DO 10 K=1,2
   10 TPSG(K,I)=0.0
      DO 50 IX=1,IXX
      J=1
C
C        READ DBM AND TIMES FOR EACH SOURCE
C
      DO 20 I=1,NUMSR
C*********************************************************************
C       READ IN THE NUMBER OF SETS OF CALIBRATION SIGNALS   ***********
C        AND THE CORRESPONDING TIMES   ********************************
C*********************************************************************
C
C          READ NUMBER OF CAL POINTS FOR EACH SOURCE --- ARPMP CARD #6
C
      READ (5,80) CALSE(I,2)
      WRITE (6,90) CALSE(I,2)
C
C          SET STARTING AND ENDING ENTRY OF CAL POINT IN ARRAY CALSE
C
      CALSE(I,1)=J
      JJ=J+CALSE(I,2)-1
      ITOT=JJ
C*********************************************************************
C       READ IN THE SIGNAL IN DBM AND THE   **************************
C        CORRESPONDING TIMES *****************************************
C*********************************************************************
C
C       READ SIGNAL DBM AND TIMES ARPMP CARD #7
C
      READ (5,110) ((CALMV(K),IHR(K),IMIN(K),ISEC(K)),K=J,JJ)
      WRITE (6,100) ((CALMV(K),IHR(K),IMIN(K),ISEC(K)),K=J, JJ)
   20 J=JJ+1
      DO 40 I=1,NUMSR
      L=CALSE(I,1)
      K=CALSE(I,2)
      LL=L+K-1
C
C     GET SIGNAL AT CALIBRATION TIME TSEC
C
      DO 40 J=L,LL
      TSEC=IHR(J)*3600.+IMIN(J)*60.+ISEC(J)
      TT=0
C
C        READ 2 SEC OF DATA FROM SIGNAL TAPE (TAPE10)
C
      DO 30 JJ=1,4
      CALL SIGNAL (TSEC,SIG)
      TT=TT+SIG(I)
   30 TSEC=TSEC+.5
   40 TPSG(IX,J)=TT/4.0
      WRITE (6,130) (IHR(J),IMIN(J),ISEC(J),CALMV(J),TPSG(IX,J),J=1,LL)
   50 CONTINUE
      DO 60 I=1,ITOT
   60 CALSG(I)=(TPSG(1,I)+TPSG(2,I))/IXX
      DO 70 I=1,NUMSR
      L=CALSE(I,1)
      LL=L-1+CALSE(I,2)
      WRITE (6,120) I,((CALMV(J),CALSG(J)),J=L,LL)
   70 CONTINUE
C
   80 FORMAT (I10)
   90 FORMAT (1H0,35HTHE NUMBER OF CALIBRATION SETS ARE ,1X,I2)
  100 FORMAT (1H0,33HTHE CALIBRATION SIGNAL IN DBM IS ,F10.4,/,1X,26HTHE
     1 CORRESPONDING TIME IS ,I2,1X,3HHRS,1X,I2,1X,4HMINS,1X,I2,1X,4HSEC
     2S)
  110 FORMAT (4(F10.4,4X,3I2))
  120 FORMAT (1H0,15H SOURCE NUMBER ,I2,/,5(20H SIGNAL DBM  SIGNAL ),/,2
     10(10(1X,F9.1),/))
  130 FORMAT (1H0,5(22H TIME Z  DBM   SIGNAL ),/,20(5(1X,3I2,1X,F6.1,1X,
     1F7.1),/,))
      END


      FUNCTION VCAL(X,I)
C*********************************************************************
C         FUNCTION VCAL PERFORMS SIGNAL CALIBRATION, I=SOURCE NUMBER-**
C         AND X = SIGNAL TO BE CALIBRATED       ***********************
C*********************************************************************
      COMMON ITYPE,NUMSR,IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,RDSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      INTEGER CALSE
```

```
      NN=CALSE(I,2)
      MM=CALSE(I,1)
      DO 60 K=1,NN
      J=K
      N=MM+J-1
C
C        IF SIGNAL CAL ARRAY IS ASCENDING -- GO TO 10
C
      IF (CALSG(MM).GT.CALSG(MM+NN-1)) GO TO 10
      IF (X.GT.CALSG(N)) GO TO 50
      GO TO 20
   10 IF (X.LT.CALSG(N)) GO TO 50
   20 IF (J.EQ.1) GO TO 40
C
C        PERFORM LINEAR EXTRAPOLATION TO FIND SIGNAL CALIBRATION
C
   30 VCAL=CALMV(N-1)+(CALMV(N)-CALMV(N-1))*(X-CALSG(N-1))/(CALSG(N)-CAL
     1SG(N-1))
      RETURN
   40 N=N+1
      GO TO 30
   50 IF (J.EQ.NN) GO TO 30
   60 CONTINUE
      END


      FUNCTION IWRD(I)
C     ******************************************************************
C          THIS FUNCTION EXTRACTS THE I TH 16 BIT WORD FROM THE 60 BIT **
C             WORDS IN IDATA  ******************************************
C     ******************************************************************
      COMMON ITYPE,NUMSR,       IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2 CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3 NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4 RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     5 FREQ(20),IMULT
      COMPLEX REF
      M2=7777B
      M1=177777B
      M3=17B
      M4=377B
C
C        CALCULATES WHICH 60 BIT WORD THE 16 BIT WORD WILL BE IN
C
      M=FLOAT(I)/15.00001
      II=I-M*15
      JJ=4*M+1
      IW1=IDATA(JJ)
      IW2=IDATA(JJ+1)
      IW3=IDATA(JJ+2)
      IW4=IDATA(JJ+3)
      IF (II.LT.1.OR.II.GT.15) II=1
C
C         GO TO THE CORRECT STATEMENT TO GET THE WORD
C
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120,130,140,150), II
   10 IWRD=AND(SHIFT(IW1,16),M1)
      RETURN
   20 IWRD=AND(SHIFT(IW1,32),M1)
      RETURN
   30 IWRD=AND(SHIFT(IW1,48),M1)
      RETURN
   40 IWRD=OR(SHIFT(AND(IW1,M2),4),AND(SHIFT(IW2,4),M3))
      RETURN
   50 IWRD=AND(SHIFT(IW2,20),M1)
      RETURN
   60 IWRD=AND(SHIFT(IW2,36),M1)
      RETURN
   70 IWRD=AND(SHIFT(IW2,52),M1)
      RETURN
   80 IWRD=OR(SHIFT(AND(IW2,M4),8),AND(SHIFT(IW3,8),M4))
      RETURN
   90 IWRD=AND(SHIFT(IW3,24),M1)
      RETURN
  100 IWRD=AND(SHIFT(IW3,40),M1)
      RETURN
  110 IWRD=AND(SHIFT(IW3,56),M1)
      RETURN
  120 IWRD=OR(SHIFT(AND(IW3,M3),12),AND(SHIFT(IW4,12),M2))
      RETURN
  130 IWRD=AND(SHIFT(IW4,28),M1)
      RETURN
  140 IWRD=AND(SHIFT(IW4,44),M1)
      RETURN
  150 IWRD=AND(IW4,M1)
      RETURN
      END


      SUBROUTINE SETTIME
C     ******************************************************************
C         THIS SUBROUTINE SETS ARRAY DTIM WITH THE ENTRY LOCATION AND ***
C           TOTAL TIME IN SECONDS AT EACH MILLISECOND ENTRY IN THE  *****
C           SIGNAL RECORD (FROM TAPE10) ***********************************
C     ******************************************************************
      COMMON ITYPE,NUMSR,       IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2 CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3 NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
```

```
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
C
C        GET END TIME OF SIGNAL RECORD
C
      CALL TTIME (IHR,MIN,ISEC,TSEC)
      IFT=0
      ASEC=0.
      ILAST=9999
      NN=IWRD(2)
      IF (NN.GT.1920) NN=1920
C
C        COUNT THE NUMBER OF SECOND CHANGES IN RECORD
C
      DO 20 I=5,NN,2
      IT=MILSEC(IWRD(I-1))
      IF (IWRD(I).NE.ITTAG) GO TO 20
      IF (IT.GT.ILAST) GO TO 10
      ASEC=ASEC+1
   10 ILAST=IT
   20 CONTINUE
      ILAST=9999
      ST=AINT(TSEC)-ASEC
      M=0
      II=1
C
C         SET ENTRY IN DTIM(M,1) AND TIME OF ENTRY IN DTIM(M,2)
C
      DO 40 I=5,NN,2
      IF (IWRD(I).NE.ITTAG) GO TO 40
      M=M+1
      IT=MILSEC(IWRD(I-1))
      DTIM(M,1)=I
      DTIM(M,2)=ST+FLOAT(IT)/1000.
      IF (IT.GT.ILAST) GO TO 30
      DTIM(M,2)=DTIM(M,2)+1.
      ST=ST+1.
   30 ILAST=IT
   40 CONTINUE
C
C         NUMD = NUMBER OF VALID ENTRIES IN ARRAY DTIM
C
      NUMD=M
      END


      SUBROUTINE TTIME (ITOTHR,ITOTMIN,ITOTSEC,TTM)
C**********************************************************************
C        THIS SUBROUTINE EXTRACTS THE END TIME OF THE SIGNAL  **********
C         RECORD FROM THE LAST 48 BITS     ****************************
C**********************************************************************
      COMMON ITYPE,NUMSR,      IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     2  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     3  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     4  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     5  FREQ(20),IMULT
      COMPLEX REF
      MWD1=78
      I=IWRD(2)
      MWD2=178
      MWD3=38
C
C        IF DAY EQUAL START DAT PLUS 1 --- SET DAY = 1 TO ADD
C         24X3600 SECONDS TO TOTAL TIME
C
      IF (DAYS.EQ.1) GO TO 10
      IUDY=AND(SHIFT(IWRD(I),-6),MWD2)
      ITDY=AND(SHIFT(IWRD(I),-10),MWD2)
      IHDY=AND(SHIFT(IWRD(I),-14),MWD3)
      IDAY=IUDY+ITDY*10+IHDY*100
      IF (IDAY.EQ.ISTDAT+1) DAYS=1.0
   10 ISEC=AND(IWRD(I+1),MWD2)
      ITSEC=AND(SHIFT(IWRD(I+1),-4),MWD1)
      ITOTSEC=ISEC+10*ITSEC
      IMIN=AND(SHIFT(IWRD(I+1),-7),MWD2)
      ITMIN=AND(SHIFT(IWRD(I+1),-11),MWD1)
      ITOTMIN=IMIN+10*ITMIN
      IHR=AND(IWRD(I),MWD2)
      ITHR=AND(SHIFT(IWRD(I),-4),MWD3)
      ITOTHR=IHR+10*ITHR
      TTM=ITOTHR*3600+ITOTMIN*60+ITOTSEC+FLOAT(MILSEC(IWRD(I+2)))/1000.+
     1DAYS*24.0*3600.0
      RETURN
      END


      SUBROUTINE IDFUN(ICR)
      DIMENSION ICR(8),ICHAR(117),ICH(10)
      INTEGER SSCRIP
COMMENT
COMMENT
COMMENT          "SSCRIP"
COMMENT               EXTERNAL FUNCTION TO SECURE TABLE SUBSCRIPT
COMMENT               TO OBTAIN DISPLAY CODE EQUIVALENT OF AN EBCDIC CODE
COMMENT
COMMENT          THE FOLLOWING TABLE DESCRIBES THE RELATIONSHIP BETWEEN
COMMENT          ALPHANUMERIC ICHARACTERS, THEIR EBCDIC CODE( IN BOTH OCTA
```

```
COMMENT          AND DECIMAL FORM), INTERNAL DISPLAY CODE (OCTAL), AND
COMMENT          THEIR ORDER NUMBER WITHIN *CICHAR* ARRAY... SORT IS BY
COMMENT          ORDER NUMBER.
COMMENT
COMMENT
COMMENT         ORDER ICHAR EBCDIC DEC DSPC      ORDER ICHAR EBCDIC DEC DS
COMMENT
COMMENT           1          100    64   55        81    N    325   213   16
COMMENT          12     .    113    75   57        82    O    326   214   17
COMMENT          13     )    114    76   52        83    P    327   215   20
COMMENT          17     +    120    80   45        84    Q    330   216   21
COMMENT          28     $    133    91   53        85    R    331   217   22
COMMENT          29     *    134    92   47        94    S    342   226   23
COMMENT          33     -    140    96   46        95    T    343   277   24
COMMENT          34     /    141    97   50        96    U    344   228   25
COMMENT          44     ,    153   107   56        97    V    345   229   26
COMMENT          45     (    154   108   51        98    W    346   230   27
COMMENT          60     =    173   123   54        99    X    347   231   30
COMMENT          61     A    301   193   01       100    Y    350   232   31
COMMENT          62     B    302   194   02       101    Z    351   233   32
COMMENT          63     C    303   195   03       108    0    360   240   33
COMMENT          64     D    304   196   04       109    1    361   241   34
COMMENT          65     E    305   197   05       110    2    362   242   35
COMMENT          66     F    306   198   06       111    3    363   243   36
COMMENT          67     G    307   199   07       112    4    364   244   37
COMMENT          68     H    310   200   10       113    5    365   245   40
COMMENT          69     I    311   201   11       114    6    366   246   41
COMMENT          77     J    321   209   12       115    7    367   247   42
COMMENT          78     K    322   210   13       116    8    370   248   43
COMMENT          79     L    323   211   14       117    9    371   249   44
COMMENT          80     M    324   212   15
COMMENT
COMMENT
COMMENT          ALL CICHAR ELEMENTS NOT USED ARE SET TO \
C
C
      DATA ICHAR / 1H ,10*1H\,1H.,1H),3*1H\,1H+,10*1H\,1H$,1H*,3*1H ,
     1  1H-,1H/,9*1H\,1H,,1H(,14*1H\,1H=,1HA,1HB,1HC,1HD,1HE,1HF,1HG,
     2  1HH,1HI,7*1H\,1HJ,1HK,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,8*1H\,1HS,
     3  1HT,1HU,1HV,1HW,1HX,1HY,1HZ,6*1H\,1H0,1H1,1H2,1H3,1H4,1H5,1H6,
     4  1H7,1H8,1H9 /
C
C
C
C
C
COMMENT
COMMENT          IN ADDITION, THE FOLLOWING ARE INCLUDED TO PROVIDE 029 KP
COMMENT          COMPATIBILITY....
COMMENT
COMMENT         ORDER ICHAR EBCDIC DEC DSPC      ORDER ICHAR EBCDIC DEC DS
COMMENT
COMMENT          14     (    115    77   51        30    )    135    93   52
COMMENT          15     +    116    78   45        59    =    176   126   54
C                *********************************************
      KK=2
      DO 20 J=1,8
      DO 10 I=1,10,2
      KK=KK+1
      ITP=IWRD(KK)
      IT2=AND(ITP,377B)
      IT3=AND(SHIFT(ITP,-8),377B)
      ICH(I)=ICHAR(SSCRIP(IT3))
10    ICH(I+1)=ICHAR(SSCRIP(IT2))
      ENCODE(10,100,IFMT)(ICH(I),I=1,10)
      ICR(J)=IFMT
20    CONTINUE
100   FORMAT(10A1)
      END


      FUNCTION MILSEC(I)
C
C     THIS FUNCTION SETS THE MILLISECONDS FROM THE 12 BIT DECIMAL CODING
C
      K=17B
      MILSEC=AND(I,K)+10*AND(SHIFT(I,-4),K)+100*AND(SHIFT(I,-8),K)
      END


      INTEGER FUNCTION SSCRIP(II)
C
C        THIS FUNCTION IS USED TO FIND THE INDEX IN ICHAR OF IDFUN
C
      I=II
      IF (I.GT.249.OR.I.LT.64) I=65
      SSCRIP=I-63
      IF (SSCRIP.EQ.63) SSCRIP=59
      IF (SSCRIP.GT.129) SSCRIP=SSCRIP-69
      END


      SUBROUTINE PAMS (VAD,VED,TR,TA,TE,VH,VP,VR)
C     ****************************************************************
C        THIS SUBROUTINE CALCULATES THE DEPRESSION ANGLE AND ASPECT ****
C         ANGLE OF THE A/C, DOCUMENTATION OF THE EQUATIONS CAN BE ******
C         FOUND IN RADC-TR-74-174 PAMS AIRBONRE INSTRUMENTATION   ******
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C         PAGE 127     ****************************************************
C       PAMS AMS COORDINATE TRANSFER EQUATIONS *****************
C         INPUT:      *****************************************
C       TR  = TRACKER RANGE TO VEHICLE IN METERS *****************
C       TE  = TRACKER ELEVATION    *****************************
C       TA  = TRACKER AZIMUTH    ******************************
C       VH  = VEHICLE HEADING    ******************************
C       VP  = VEHICLE PITCH      ******************************
C       VR  = VEHICLE ROLL       ******************************
C           OUTPUT:     ***************************************
C       VE  = VEHICLE ELEVATION ( TO SITE )   *****************
C       VA  = VEHICLE AZIMUTH                 *****************
C       RE  = RADIUS OF SPHERE HAVING EARTHS VOLUME IN METERS  **
C       VY1= FIRST YAW ANGLE  *********************************
C       VP1= FIRST PITCH ANGLE (COMPUTED)   ********************
C       VY2= SECOND YAW ANGLE (COMPUTED)   *********************
C     *********************************************************
C          CORRECTION FOR MAGNETIC VARIATION
C
      VH=VH+15.
      IF (VH.GT.360.) VH=VH-360
      DTR=.01745329252
      RE=6361696.421
      VH=VH*DTR
      TE=TE*DTR
      TA=TA*DTR
      VP=VP*DTR
      VR=VR*DTR
      R180=180.*DTR
      R360=360.*DTR
      RORE=TR/RE
      SE=SIN(TE)
      CE=COS(TE)
      SA=SIN(TA)
      CA=COS(TA)
      H=RE*(SQRT(1.+RORE*(RORE+2.*SE))-1.)
      GAMAN=ATAN(TR*CE/(RE+TR*SE))
      CGN=COS(GAMAN)
      SGN=SIN(GAMAN)
      VP1=-GAMAN
      IF (TA.GT.R180) GO TO 10
      TA1=TA
      GO TO 20
   10 TA1=R360-TA
   20 STA1=SIN(TA1)
      CTA1=COS(TA1)
      VB=ATAN2(STA1,(.6975275*SGN-CGN*CTA1))
      IF (TA.LE.R180) GO TO 30
      VH1=R180-VB
      GO TO 40
   30 VH1=VB-R180
   40 VY2=VH1+VH
      XO=-TR*CE
      YO=0.
      ZO=TR*SE
C
C          ROTATION SEQUENCE IS VP1,VY2,VP,VR   ***************
C
      CP1=COS(VP1)
      SP1=SIN(VP1)
      CY2=COS(VY2)
      SY2=SIN(VY2)
      CP=COS(VP)
      SP=SIN(VP)
      CR=COS(VR)
      SR=SIN(VR)
C     ***************************************************
      XV=XO*(CP1*CY2*CP-SP1*SP)+YO*SY2*CP-ZO*(SP1*CY2*CP+CP1*SP)
      YV=XO*(CP1*CY2*SP*SR-CP1*SY2*CR+SP1*CP*SR)+YJ*(SY2*SP*SR+CY2*CR)-Z
     10*(SP1*CY2*SP*SR-SP1*SY2*CR-CP1*CP*SR)
      ZV=XO*(CP1*CY2*SP*CR+CP1*SY2*SR+SP1*CP*CR)+YO*(SY2*SP*CR-CY2*SR)-Z
     10*(SP1*CY2*SP*CR+SP1*SY2*SR-CP1*CP*CR)
      VA=ATAN2(YV,XV)
      VE=ATAN2(-ZV,SQRT(XV*XV+YV*YV))
      VAD=VA/DTR
      IF (VAD.LE.0.0) VAD=VAD+360.0
      VED=VE/DTR
      RETURN
      END


      SUBROUTINE MULTPTH (RANG ,ISR,ICKMP,DBGAIN)
C     *********************************************************
C          THIS SUBROUTINE CALCULATES THE EFFECT OF MULTIPATH      *******
C          RADIATION. THE TECHNIQUE USED IS DOCUMENTED IN THE      *******
C          FLIGHT MEASUREMENT OF A/C ANTENNA RADIATION PATTERNS REPORT **
C     *********************************************************
      COMMON ITYPE,NUMSR,      IDATA(512),ITTAG,IDATAG(20),ISTWD,IWD,
     1  CALSG(200),CALMV(200),CALSE(20,2),IHED(90),TIM1(90),TIM2(90),
     2  NUMHD,IHDTYP,DTIM(500,2),NUMD,DELDB(20),HD2,IXX,IRADAR,NUMRNG,
     3  RDRNG(3,20),ALTAC,DAYS,DAYR,ISTDAT,ROSTT,ANTHT(20),REF(20),
     4  FREQ(20),IMULT
      COMPLEX NN,RR,RT,REF
      NN=REF(ISR)
      H1=ANTHT(ISR)
      TALT=ALTAC
      POL=1
      RANGE=1.149*RANG
C
```

```
C     FIND CORRECT DIST 1
C
      CALL DDIST (RANGE,H1,TALT,DIST1,ICKMP,H2PRI)
      IF (ICKMP.EQ.1.0) GO TO 40
      ARG2=H1/(5280.0*DIST1)
C
C     FIND ANGLE OF INCID/REFLEC
C
      SI=(ATAN(ARG2))
      RT=CSQRT(NN-COS(SI)**2)
C
C     FIND REFLEC COEF AND ANGLE
C
      IF (1.0-POL) 10,10,20
   10 RR=(NN*SIN(SI)-RT)/(NN*SIN(SI)+RT)
      GO TO 30
   20 RR=(    SIN(SI)-RT)/(SIN(SI)+RT)
   30 D=SQRT(1.0+((2.0*DIST1)*(RANGF-DIST1)**2)/(RANGE*H2PRI))
      RMAG=SQRT(REAL(RR)**2+AIMAG(RR)**2)
      PHI=ATAN2(AIMAG(RR),REAL(RR))
      IF (SI.GT..2) GO TO 50
      DIV=1.0/D
C
C     CALCULATE THETA
C
      H3=H1-DIST1**2/2.0
      THETA=(0.0001385*H3*H2PRI*FREQ(ISR))/57.3/RANGE
      ANGLE3=THETA-PHI
      GAIN=1.0+(DIV*RMAG)**2+2.0*DIV*RMAG*COS(ANGLE3)
      DBGAIN=10*ALOG10(GAIN)
   40 RETURN
   50 ICKMP=1
      END
```

```
      SUBROUTINE DDIST (RANGE,H1,TALT,DIST1,ICKMP,H2PRI)
C
C        CALCULATES DISTANCE FROM ANTENNA TO REFLECTING POINT
C        FOR MULTPTH
C
      DIST1=0.0
      DH=1.414*(SQRT(H1)+SQRT(TALT))
      IF (DH.LT.RANGE) GO TO 60
      DO 10 I=1,200
      DIST1=0.1+DIST1
      IF (DIST1.GT.RANGE) GO TO 60
      H3=H1-DIST1**2/2.0
      H2PRI=H3*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 20
   10 CONTINUE
   20 DIST1=DIST1-.1
      DO 30 I=1,100
      DIST1=0.01+DIST1
      H3=H1-DIST1**2/2.0
      H2PRI=H3*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) GO TO 40
   30 CONTINUE
   40 DIST1=DIST1-.01
      DO 50 I=1,100
      DIST1=0.001+DIST1
      H3=H1-DIST1**2/2.0
      H2PRI=H3*(RANGE-DIST1)/DIST1
      H2SEC=((RANGE-DIST1)**2)/2.0
      H2TOT=H2PRI+H2SEC
      IF (TALT.GE.H2TOT) RETURN
   50 CONTINUE
   60 ICKMP=1.0
      END
```

LIST OF ABBREVIATIONS AND SYMBOLS

Item	Definition	Units
a	earth radius	statute miles
ADAP	Antenna Data Analysis Program	- - -
AFFTC	Air Force Flight Test Center	- - -
AM	amplitude modulation	- - -
AMS	airborne monitoring system	- - -
ARPMP	Antenna Radiation Pattern Measurement Program	- - -
CPU	central processing unit	- - -
CW	continuous wave	- - -
D	divergence factor	- - -
db	decibel	- - -
$db_{(L)}$	line loss	db
dbm	db above a milliwatt dbm = $10 \log \left(\frac{P_w}{.001}\right)$	- - -
dbw	db above a watt dbw = $10 \log (P_w)$	- - -
DFVLR	German Research and Test Facility for Aerodynamics and Space Flight	- - -
E_i	incident electric field intensity vector	volts/meter
E_0	free space electric field intensity vector	volts/meter
E_r	reflected electric field intensity vector	volts/meter
E_R	resultant electric field intensity vector	volts/meter
f	frequency	Hz
FM	frequency modulation	- - -
f_{MHz}	frequency in megahertz	Hz x 10^6
GHz	gigahertz (10^9 cycles per second)	- - -
G_M	gain due to multipath signal	db
G_R	gain of receiving antenna	db

Item	Definition	Units
G_T	gain of transmitting antenna	db
$g(\theta)$	earth gain factor	- - -
k	factor to correct for atmospheric refraction	- - -
L	line loss	db
MHz	megahertz (10^6 cycles per second)	- - -
n	index of refraction	- - -
NATC	Naval Air Test Center	- - -
PAMS	Precision Antenna Measurement System	- - -
P_w	power	watts
P_r	power received	dbm
$\mathcal{R}$	reflection coefficient	- - -
R	$\|\mathcal{R}\|$	- - -
RADC	Rome Air Development Center	- - -
RAPCON	radar approach control	- - -
RF	radio frequency	- - -
R_N	range	NM
SAMTEC	Space and Missile Test Center	- - -
UHF	ultra high frequency	- - -
VHF	very high frequency	- - -
VSWR	voltage standing wave ratio	- - -
ε	permittivity	farad/meter
ε_0	permittivity of free space $1/(36\pi \times 10^9)$	farad/meter
ε_{r1}	relative permittivity of air	- - -
ε_{r2}	relative permittivity of earth surface	- - -
θ	phase change due to path length	degrees
σ_2	conductivity	mho-meters/meters^2

Item	Definition	Units
ϕ	phase change due to reflection	degrees
ψ	grazing angle	degrees
ω	frequency	radian per sec